White-throated snapping turtle *Elseya* sp.aff. *dentata*. See paper on page 48.
(Photo by Grant Turner).

Male combat in *Austrelaps labialis*. See paper on page 17.
(Photo by J. Dallwitz).

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CONTENTS

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HERPETOLOGICAL NOTES

SURVEYS OF REPTILES AND AMPHIBIANS ON THE SOUTH-WESTERN SLOPES OF NEW SOUTH WALES

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ABSTRACT

Systematic surveys of 58 sites in fourteen reserves and 9 sites on private property on the south-west slopes of New South Wales recorded a total of 28 species of reptile. An additional five species were detected within these reserves opportunistically. A total of 10 species of frog were detected. Several species of reptile observed during the survey represent extensions to previously recorded distributions. Many species of reptile had a patchy distribution as a consequence of clearing for agriculture and associations with rock outcrops on ridgelines. The presence of rock outcrops, loose rock and litter were significant habitat components for many species of reptile. This type of habitat had the richest lizard fauna. The Booroolong Frog *Litoria booroolongensis*, currently listed as endangered on the Threatened Species Conservation Act (1995) of NSW was found at Journama Creek. Exotic species of fish were present in the non-perennial creeks and are a threat to the continued existence of the Booroolong Frog.

INTRODUCTION

Pre-European vegetation communities on the southwest slopes of New South Wales have become highly fragmented as a result of clearing for agriculture. The forests which occurred on the more fertile soils in flat country have been extensively cleared for agriculture. Since European settlement more than 85% of Australia's temperate woodlands have been cleared, making this community the most endangered and poorly conserved vegetation type in Australia (Benson, 1991). The remaining native forests are now mainly confined to areas of steep slope and low soil fertility. With the exceptions of Mundoonen NR and Dananbilla NR, the portions of land which constitute the Nature Reserves and National Parks surveyed as part of the following study have recently come into the reservation system as part of the Regional Forest Agreement (gazetted 1 January 2001).

The study area had several transitional zones of native vegetation. To the north and west of the study area the forests were drier than those which occurred close to the Kosciuszko Range. Few studies on herpetofauna had been conducted in this region. Caughley and Gall (1985) conducted wide-ranging surveys and considered zoogeographic trends. Annable (1995) and Murphy (1997) conducted surveys on reptiles and frogs respectively around Wagga Wagga. Lemckert (1998) conducted surveys for herpetofauna in twelve State Forests but concentrated on the more mesic forests associated with the Kosciuszko Range. Woomargama NP and Ellerslie NR were the only areas in common with the current survey.

Fauna surveys of reserves in the south-west slopes region of New South Wales (Figure 1) were conducted to investigate the species diversity and distribution in the current reserve system. Reptiles and amphibians were surveyed systematically for the NSW NPWS as part of a broader survey to sample the terrestrial fauna on land that had come into the reservation system as part of the Regional Forest Agreement. Survey sites were stratified according to topography (gully, midslope and ridge lines). Targeted and opportunistic surveys were also conducted to provide a more comprehensive species inventory and distribution.

This paper describes the reptile and amphibian communities of these reserves on the New South Wales south-west slopes and also comments on management options that may aid the conservation of the existing species.

Figure 1. Survey sites on south-western slopes of New South Wales.

Figure 1. Survey sites on south-western slopes of New South Wales.
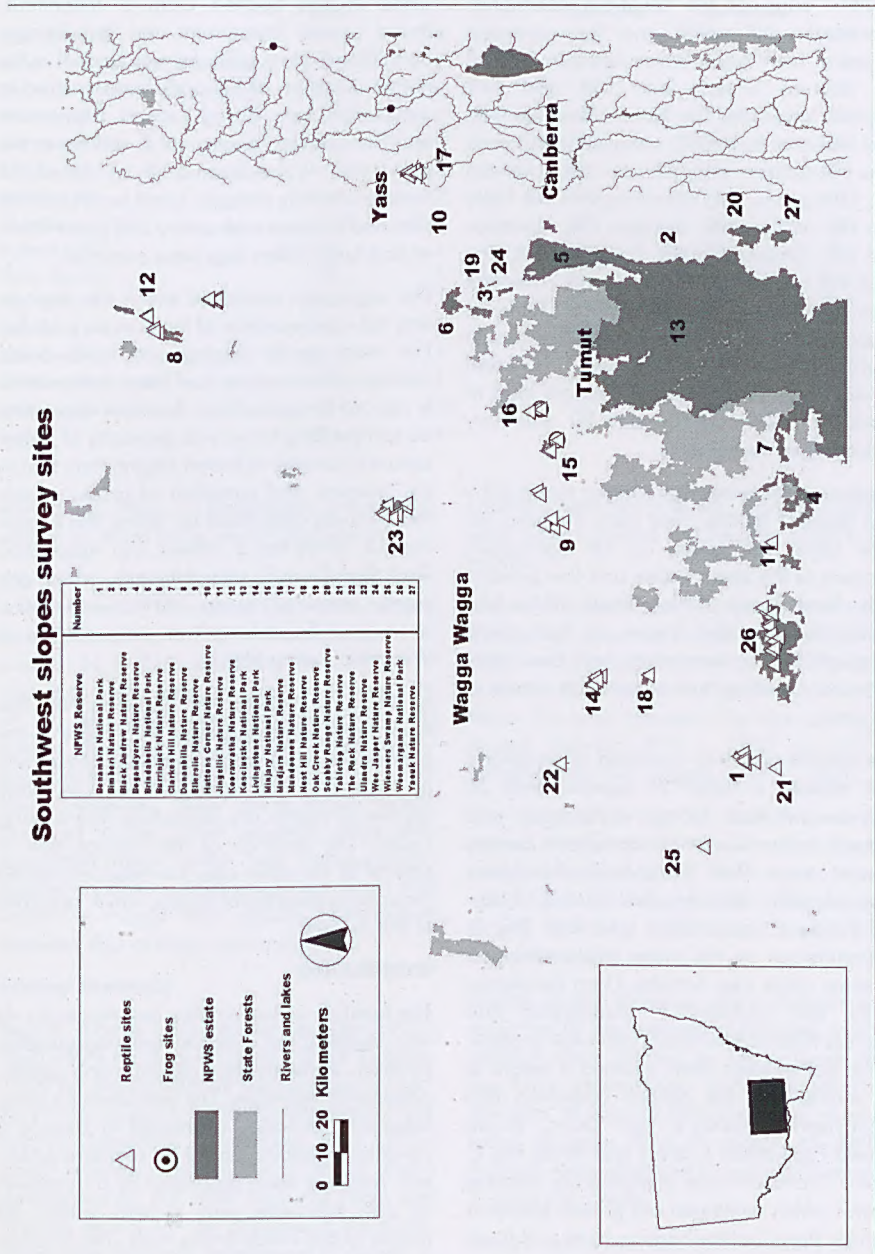
METHODS

Study Area

The south-west slopes region includes the western edge of the Southern Tablelands (Kosciuszko NP uplift) and the southwest slopes of New South Wales between 34 and 36 degrees latitude and 147 and 149 degrees longitude. The Nature Reserves (NR) and National Parks (NP) surveyed in this area were Benambra NR, Ellerslie NR, Ulandra NR, Livingstone NR, Woomargama NP, Table Top NR, Minjery NR, Mudjarn NR, Mundoonen NR, Tumberlong NR, Pullentop NR, The Rock NR and Wiesners Swamp NR. The total area surveyed was 48649 hectares (Table 1). Opportunistic surveys were conducted beside Journama Creek in Kosciuszko NP and surveys were conducted on freehold land in association with assessments for voluntary conservation agreements.

In general, the areas had rugged topography and low soil fertility. They were the land left over from that taken up for agriculture because of the steep slopes and low productivity. State Forest of New South Wales had previously managed many of the areas, although timber harvesting had been very selective. Grazing had occurred at many of the sites.

The habitat primarily consisted of woodland that attained a height of approximately 20 metres and had sparse understorey and ground cover. Common dominant canopy species were Red Stringybark *Eucalyptus macrorhyncha*, Blakely's Red Gum *E. blakelyi*, Bundy *E. goniocalyx* and Red Box *E. polyanthemos* on the ridges and midslopes. At some ridge sites Scribbly Gum *Eucalyptus rossii*, Red Ironbark *E. sideroxylon* and Cypress Pine *Callitris endlicheri* were present. In the gullies trees often attained a height to 25 metres and the canopy contained Red Stringybark, Blakely's Red Gum, Broad Leaved Peppermint *E. dives* and White Box *E. albens*. Transects were preferentially selected at sites which contained old growth elements such as stags, hollow bearing trees and large fallen logs.

Woomargama NP was more mesic than the other forests surveyed and attained a height of approximately 30 metres. The canopy species in the ridge and midslope sites consisted of Red Spotted Gum *E. mannifera*, Broad Leaved Peppermint and Red Stringybark. Blue Gum *E. globulus* was present in the northern section of the park and occurred in association with Broad Leaved Peppermint and Fine Leaved Peppermint *E. radiata* at the gully sites. Woomargama NP contained the most structurally complex forest surveyed. The sites had a dense midcanopy and groundcover and large fallen logs were common.

The vegetation contained within the reserves was not representative of the area as a whole. The more gently sloping and fertile areas outside of the reserves had been preferentially cleared for agriculture. Remnant vegetation on surrounding farms was generally of larger stature (diameter at breast height) than that in the reserves and consisted of grassy woodlands mostly dominated by Yellow Box *E. melliodora*, White Box *E. albens* and Apple Box. River Red Gum *E. camaldulensis*, which primarily occurred along permanent creeks, rivers and floodplains was only present in Wiesners Swamp NR.

In areas of Ulandra NR, Tabletop NR, The Rock and Woomargama NP there were granite outcrops, which contained loose rock on rock. This was significant because many species of reptile are saxicolous (live among rocks). The absence of this habitat type in several of the other sites surveyed influenced the species diversity of reptile, which occurred in the reserve.

Stratification

The location of survey sites (see Appendix A) was stratified by distance and topographic position. Transects were placed along gullies, ridges and midridges. The selection of a gully, ridge and midridge attempted to sample a variation in habitat based on moisture gradient. Transects were separated by a minimum of one kilometre and located within 50 metres of dirt roads or fire trails. The location (Australian Grid Reference) of sites was deter-

Table 1. Distribution of survey sites by National Park/Nature Reserve on the south-west slopes of New South Wales

Elevations are in metres Australian Height Data and refer to sampling sites.

Reservation Unit	Total Area (ha)	Sites	Min. Elevation	Max. Elevation	Mean
Benambra NR	1400	6	330	620	440
Boona and Cains private property	1087	6	575	610	600
Dananbilla NR/private property	2242	6	430	620	513
Ellerslie NR	1280	4	270	635	420
Livingstone NR	2603	5	400	460	430
Minjery NR	1460	3	390	750	575
Mudjarn NR	590	3	290	550	440
Mundoonen NR	1359	6	580	700	660
Pullentop NR	758	1	450	450	450
Table Top NR	100	1	710	710	710
The Rock NR	267	1	500	500	500
Tumblong NR	740	2	550	575	560
Ulandra NR	3960	7	440	760	550
Wiesners Swamp NR	103	1	200	200	200
Woomargama NP	30700	15	500	890	660
Total	48649	67			

mined by either a geographic positioning system or taken from topographic maps.

Elevations within the study areas ranged from 270 metres to 890 metres. Gully sites ranged from 270 metres to 700 metres (average 474 metres, N = 21), midslope sites from 330 metres to 750 metres (average 544 meters, N = 22) and ridge sites 440 metres to 890 meters (average 620, N = 24). Topographic position had a strong relationship to forest type. Generally, taller more mesic forests occurred in the gullies whereas ridge sites supported forest which was comparatively smaller in stature. Midslopes had forest that varied in height and species composition between that of ridge and gully sites.

Survey Methods

Reptile surveys were conducted from 19-22 April 1999 for Boona/Cains, 22-29 October 1999 for Dananbilla NR (plus private property) 21-24 February 2000 for Mundoonen NR and 23 October to 7 December 2001 for the other reserves. The methods follow those determined by the NSW National Parks and Wildlife Service for the purpose of the Comprehensive Regional Assessment of forests in southern New South Wales. Standard surveys were based around a 2 hectare (100 x 200 m) site.

Diurnal herpetofauna surveys involved either the author surveying for 60 minutes (62% of sites) or two people surveying for 30 minutes. A total of 60 minutes search effort was undertaken for each transect. Surveys were conducted between 920 - 1300 hrs EST at temperatures that ranged from 8 - 28°C.

Five targeted surveys for reptiles were conducted at ridge sites. These were in areas that contained rock outcrops. These transects were often linear and longer than 200 metre in length. However, a 60 minute search effort was maintained.

During reptile searches active animals were observed as they basked or foraged. Inactive animals were located by lifting loose rock, logs and decorticating bark and searching leaf litter. At one site (Ulandra ridge) sheets of loose tin were lifted in search of reptiles. Animals were identified by sight and generally were not caught.

Frogs were surveyed systematically at two

Table 2. Vegetation communities at selected survey sites by National Park/Nature Reserve on the south-west slopes of New South Wales

NR = Nature Reserve, NP = National Park. Species are given in order of ascending height.

Reservation Unit	Canopy Species at Survey Sites	Max. Height (m)
Benambra NR	Ridge: *Eucalyptus macrorhyncha, E. blakelyi*	18
	Midridge: *E. blakelyi, E. goniocalyx* and *E. macrorhyncha*.	25
	Gully: *E. macrorhyncha, E. polyanthemos* and *E. albens*.	25
Ellerslie NR	Ridge: *E. dives, E. rossii, E. blakelyi/E. sideroxylon, E. polyanthemos, E. macrorhyncha* and *E. blakelyi*.	18
	Gully: *E. dives, E. blakelyi* and *E. macrorhyncha*.	20
Livingstone NR	Ridge: *E. rossii, E. sideroxylon* and *E. macrorhyncha*.	12
	Midridge: *E. rossii*.	10
	Gully: *E. sideroxylon, E. albens, E. blakelyi* and *E. rossii*.	20
Minjery NR	All sites: *E. macrorhyncha, E. polyanthemos, E. goniocalyx* and *E. blakelyi*.	25-8
Mudjarn NR	Gully and ridge: *E. macrorhyncha, E. blakelyi* and *Callitris endlicheri*.	12
	Midridge: *E. goniocalyx, E. polyanthemos* and *Callitris endlicheri*.	10
Mundoonen NR	Ridge: *E. rossii, E. macrorhyncha, E. goniocalyx* and *E. polyanthemos*.	10
	Midridge: *E. macrorhyncha, E. rossii* and *E. goniocalyx*.	10
	Gully: *E. mannifera, E. macrorhyncha, E. melliodora* and *E. bridgesiana*.	20
Pullentop NR	Midridge: *E. macrorhyncha, E. rossii* and *E. polyanthemos*.	12
Table Top NR	Ridge: *E. dwyeri, E. macrorhyncha* and *Acacia doratoxylon*.	8
Tumblong NR	Ridge: *E. rossii, E. macrorhyncha, E. goniocalyx* and *E. sideroxylon*.	18
	Midridge: *E. albens, E. macrorhyncha* and *E. goniocalyx*.	15
Ulandra NR	Ridge: *E. albens* and *Acacia baileyana*.	10
	Midridge: *E. blakelyi, E. albens* and *Callitris endlicheri*.	15
	Gully: *E. blakelyi, E. albens* and *E. macrorhyncha*.	15
Woomargama NP	Northern Portion: Ridge: *E. mannifera, E. macrorhyncha* and *E. dives*.	28
	Midridge: *E. mannifera, E. radiata, E. dives* and *E. macrorhyncha*.	28
	Gully: *E. globulus, E. radiata* and *E. dives*.	30
	Southern Portion: Ridge: *E. mannifera, E. macrorhyncha* and *E. dives*.	20
	Midridge: *E. dives, E. macrorhyncha* and *E. mannifera*.	28
	Gully: *E. mannifera, E. radiata* and *E. macrorhyncha*.	20
Weisners Swamp NR	Gully: *E. camalduensis*.	20
Dananbilla NR, private property	Ridge: *E. rossii, E. sideroxylon* and *Callitris endlicheri*.	12
	Midridge: *E. dwyeri, Callitris endlicheri/ E. sideroxylon* and *E. albens*.	12
	Gully: *E. sideroxylon, E. macrorhyncha, E. blakelyi, E. albens, Callitris endlicheri*.	25
Boona and Cains, private property	Ridge: *E. sideroxylon, E. polyanthemos* and *E. macrorhyncha*.	12
	Midridge: *E. sideroxylon, E. polyanthemos, E. blakelyi* and *E. macrorhyncha*.	20
	Gully: *E. blakelyi*.	12

sites on 26 and 27 November 2001 by spotlighting for a period of 30 min along creeklines. Frogs were either observed, identified by their calls and/or the morphology of tadpoles. Freshwater fish were also identified during the frog surveys. There were few non-perennial creeks in the study area and this restricted the number of streamside transects sampled.

Additional observations of animals were made outside the systematic and targeted surveys. These observations occurred while driving between sites, at sites outside the dedicated period for systematic or targeted surveys or at additional sites. Over 2000 kilometres were covered during drive transects. The position of species detected during these surveys was recorded.

RESULTS

Plot based and opportunistic data

Systematic surveys recorded a total of 28 species of reptile. Five additional species were detected within one kilometre of the reserves/private property opportunistically. Snakes were found less commonly than lizards. Small lizards (less then 200 mm in total length) were more commonly detected than larger lizards. The larger skinks, dragons and goannas were rarely detected during systematic surveys and were mainly observed while driving between sites. Incidental observations made outside the study areas included Snake-necked Turtle *Chelodina longicollis* (between Cootamundra and Tamora) and Carnaby's Skink *Cryptoblepharus carnabyi*, Striped Skink *Ctenotus robustus* and Boulenger's Skink *Morethia boulengeri* within the urban area of Albury.

Surveys for frogs revealed the presence of fourteen species. Frogs were found around fire dams and along creeks. Two systematic surveys were conducted one at Killamacat Creek (on freehold land next to Mudjarn NR) and one at Minjery NR. The Broad Palmed Frog *Litoria latopalmata* (N = 4), Lesueur's Frog *Litoria* sp. affin. *lesueuri* (N = 43) and Plain Froglet *Crinia parinsignifera* (N = 2) were detected along Killamacat Creek. The Broad Palmed Frog (N = 1) and Common Eastern Froglet *Crinia signifera* (N = 3) were detected in Minjery NR. Two subadult Booroolong Frogs *Litoria booroolongensis* were observed beside Journama Creek.

Carp *Cyprinus carpio* were observed in Killamacat Creek and Mountain Galaxia *Galaxia olivaceous* in Minjery NR.

Environmental Gradients and Species Assemblages

Woomargama NP and Journama Creek in Kosciuszko NP supported the most mesic forests and large fallen logs were abundant in the Blue Gum gully sites. The Heatwole's Water Skink and Gippsland Water Dragon were only detected at these sites. The Black Blind Snake was found at Woomargama NP and White's Skink at Journama Creek in relatively mesic vegetation communities.

Conversely in the drier forests species such as the Olive Legless Lizard, Eastern Spiny-tailed Gecko, Thick Tailed Gecko, Bougainville's Skink, Shingleback, Spectacled Hooded Snake and Prong-snouted Blind Snake were found. However, annual precipitation (and hence forest type) may not be the sole factor influencing the distribution of the above species. The presence of large areas of exposed north facing rock outcrops was a significant factor in the distribution of some species as aspect and substrate lead to a higher degree of solar radiation and radiant heat.

Nobbi Dragon was mostly found on ridgelines in drier forest types. Lemckert (1998) did not record this species from the region but it was widespread being detected in four of the twelve reserves (Table 3).

The distributions of some species of frog were also highly associated with various forest types. Species associated with more mesic environments in the east of the study area (Woomargama NR) included the Striped Marsh Frog *Limnodynastes peroni* and Ewing's Tree frog *Litoria ewingii*. The Lord of the Swamp *Limnodynastes interioris* was found in the drier forests of Ulandra and Benambra NR's. The Broad-palmed Frog *Litoria latopalmata* was only found around the Tumut area. Sudell's Frog *Neobatrachus sudellii* and Smooth Toadlet *Uperoleia laevigata* were only found at Dananbilla NR.

Microhabitat preference of reptiles and frogs

In relation to topography (ridge, midridge or gully sites) the average species diversity and average total number of reptiles was highest at ridge sites, which had extensive areas of, exposed rock (granite) and loose rock exfoliations (Table 6). The Eastern Spiny-tailed Gecko, Thick-tailed Gecko, and Cunningham's Skink were only found at sites that contained extensive areas of rock, loose rock and

Table 3. Occurrence of reptiles by reserve/property on the south-west slopes

Records made during the survey are indicated with either O = incidental observations, o= observed within one kilometre of area. A minimum figure of 1 is given for Lace Monitors detected via scratches on trees within transects. Total Animals are given for systematic and targeted sites. C = recorded by Caughley and Gall (1985). Ul = Ulandra NR, Li = Livingstone NP, Pu = Pulletop NR, Ro = The Rock NR, Be = Benambra NR, Ta = Tabletop NR, Wo = Woomargama NP, Mu = Mudjarn NR, Mi = Minjery NR, Tu = Tumblong NR, El = Ellerslie NR, Wi = Wiesners Swamp NR, Jo = Journama Ck, Mn = Mundoonen NR, Da = Dananbilla NR, Bo = Boona & Cains, Tot = total animals.

Species		Ul	Li	Pu	Ro	Be	Ta	Wo	Mu	Mi	Tu	El	Wi	Jo	Mn	Da	Bo	Tot
Delma inornata	Olive Legless Lizard																O	N/A
Christinus marmoratus	Marbled Gecko	4	1			3,C	1		4	1	3	1				1	2	21
Diplodactylus intermedius	Eastern Spiny-tailed Gecko	4			C													4
Diplodactylus vittatus	Stone Gecko	2	C		C	1,C		5,C			1					O		9
Underwoodisaurus milii	Thick Tailed Gecko	1																1
Amphibolurus nobbi	Nobbi Dragon	3			1		3					1				1		9
Amphibolurus muricatus	Jacky Dragon	1,C	C	1		O,C		1,C	o						1			4
Physignathus lesueurii howitti	Gippsland Water Dragon							O						O				N/A
Pogona barbata	Bearded Dragon	O				C		O	o	O					o	O	1	1
Varanus varius	Lace Monitor	1,C	1,C		C	1,C		C	1	O				O		1		8
Bassiana platynota	Red-throated Skink		1,C					5,C	1									6
Carlia tetradactyla	Southern Rainbow Skink	6	2,C			2,C	o	5,C	1	7	3	4			o	1	5	31
Cryptoblepharus carnabyi	Carnaby's Skink		2,C		6,C	1	o					O				6		15
Ctenotus robustus	Striped Skink	4				C			4	1		1				O		10
Ctenotus taeniolatus	Copper-tailed Skink	4	1,C					26,C	1							1	1	34
Egernia cunninghami	Cunningham's Skink	6,C						O,C								O		6
Egernia striolata	Tree Skink	25		2	3	10,C	7	1,C	O	1		2			o	5	4	60
Egernia whitii	Whites Skink													O				N/A
Eulamprus heatwolei	Heatwole's Water Skink	C						43,C						O				43
Hemiergis decresiensis	Three-toed Skink							6,C	4			3			5			18
Lampropholis delicata	Grass Skink	14				3									8	O	2	27
Lampropholis guichenoti	Garden Skink	1,C				37,C	17	91,C				5		O		O		152
Lerista bougainvillii	Bougainville's Skink		1,C		1											2		4
Morethia boulengeri	Boulenger's Skink	21	C		O,C	2,C	3	C	1		3	2	1			8	16	57
Tiliqua scincoides	Eastern Bluetongue		C		O,C	O		C									1	1

Species		Ul	Li	Pu	Ro	Be	Ta	Wo	Mu	Mi	Tu	El	Wi	Jo	Mn	Da	Bo	Tot
Trachydosaurus rugosus	Shingleback	O,C																N/A
Ramphotyphlops bituberculata	Prong-snouted Blind Snake	1																1
Ramphotyphlops nigrescens	Black Blind Snake							1,C										1
Demansia psammophis	Yellow-faced Whip Snake											1						1
Pseudechis porphyriacus	Red-bellied Black Snake	C	C			C		O,C										1
Pseudonaja textilis	Eastern Brown Snake	1						o,C							o			1
Rhinoplocephalus nigrescens	Small-eyed Snake							2,C										2
Suta spectabilis	Spectacled Hooded Snake	1			O											O	1	2
Total Species		20	7	2	5	10	8	13	7	6	4	12	1	5	3	15	10	
Number of sites		7	5	1	1	6	1	15	4	3	2	4	1	N/A	6	6	6	
Number of individuals		100	9	3	11	60	31	190	17	11	10	21	1	N/A	14	27	33	

Table 4. Comparison of number of reptiles and species diversity at systematic sites in relation to topography

The first figure represents total species and the second figure represents total individual reptiles. Where the Lace Monitor was detected by the presence of scratches on trees a minimal figure of 1 was given. Ul = Ulandra NR, Li = Livingstone NP, Pu = Pulletop NR, Ro = The Rock NR, Be = Benambra NR, Ta = Tabletop NR, Wo = Woomargama NP, Mu = Mudjarn NR, Mi = Minjery NR, Tu = Tumblong NR, El = Ellerslie NR, Wi = Weisners Swamp NR, Jo = Journama Ck, Mn = Mundoonen NR, Da = Dananbilla NR, Bo = Boona & Cains, Tot = total sites, AvI = average individuals, AvS = average species.

Survey areas	Ul	Li	Pu	Ro	Be	Ta	Wo	Mu	Mi	Tu	El	Wi	Mn	Da	Bo	Tot	AvI	AvS
Gully	4/9	5/7	N/A	N/A	2/14	N/A	5/77	4/7	2/7	1/1	6/7	1/1	3/10	6/11	5/6	21	7.4	2.3
Midridge	12/36	1/1	2/3	N/A	3/8	N/A	4/50	3/4	3/3	N/A	N/A	N/A	1/1	5/13	7/23	22	6.6	2.7
Ridge	15/59	1/1	N/A	4/11	7/38	5/31	10/62	3/6	1/1	3/9	8/14	N/A	2/3	2/2	3/4	24	11.0	3.2
Average Individuals	14.8	1.8	3	11	10	31	12.6	5.3	3.6	5	10.5	1	2.2	4.3	5.5			

Table 5. Occurrence of frogs by reserve/property on the south-west slopes

Records made during the survey are indicated with either O for observed, H for heard in area and h for heard within one kilometre of area. Ul = Ulandra NR, Li = Livingstone NP, Be = Benambra NR, Wo = Woomargama NP, Mu = Mudjarn NR, Mi = Minjery NR, Tu = Tumblong NR, El = Ellerslie NR, Jo = Journama Ck, Mn = Mundoonen NR, Da = Danan-billa NR, Bo = Boona & Cains. *Litoria* sp. affin. *lesueuri* had yellow spots in its groin.

Species		Ul	Li	Be	Wo	Mu	Mi	Tu	El	Jo	Mn	Da	Bo
Litoria booroolongensis	Booroolong Frog									O			
Litoria ewingii	Ewing's Tree Frog				H/O								
Litoria latopalmata	Broad-palmed Frog					H/O	H	H	H				
Litoria sp. affin. *lesueuri*	Lesueur's Frog					O							
Litoria peronii	Peron's Tree Frog	H		H		H		H			O	O	O
Crinia parinsignifera	Plains Froglet	h									O	O	O
Crinia signifera	Common Eastern Froglet	H	h	H	H	H	H				H	H	H
Crinia sloanei	Sloane's Toadlet	H	h		H								
Limnodynastes dumerilii	Pobblebonk				H						O		
Limnodynastes interioris	Lord of the Swamp	O		O									
Limnodynastes peronii	Striped Marsh Frog			H	H								
Limnodynastes tasmaniensis	Spotted Grass Frog	H				O					O	O	O
Neobatrachus sudellii	Sudell's Frog											O	
Uperoleia laevigata	Smooth Toadlet										O	H	
Total Species		6	2	4	5	4	2	2	1	1	6	6	3

rock crevices.

Rocks and in particular large rock outcrops, which have exfoliating rock, were important for certain species of reptile. Nineteen percent of the total species of reptile detected during the quantitative surveys were found at sites that contained large rock outcrops on ridge-lines. Approximately one third of all reptiles observed were under rock or in rock crevices (Table 6). In particular rock crevices and exfoliations varied in the amount of space between the parent rock. Geckoes were found to utilise rock exfoliations, which had narrow spaces. These spaces were small enough that they excluded larger lizards such as the Tree Skink and/or Cunningham's Skink.

Loose rock on soil was an important micro-habitat for reptiles. Fossorial species such as Bougainville's Skink, Three-toed Skink and Blind Snakes were found under rock on soil. Coppertail Skinks were also found under rock that had soil between the parent rock. Gravid Marbled Geckoes and gecko eggs were found under rocks on soil.

Logs were a significant habitat for reptiles with thirty six percent of observations on lizards on, under or in crevices of fallen timber. Heatwole's Water Skink was highly associated with either large (500 mm diameter) fallen logs or rocks beside certain creeks.

The Marbled Gecko was mostly found under decorticating bark (76% of observations on this species). This was the only species found in this microhabitat. The species was detected under the bark of Blakely's Gum, Red Stringybark and Red Ironbark.

The majority of small skinks were observed active in leaf litter and fallen pieces of bark. This accounted for 30% of all detections (Table 6). Litter provides habitat, which the animals used for escape. Litter also provides habitat for insects that constitute the major prey items for small skinks.

Lace Monitors were observed at Livingstone NR, Benambra NR and Minjery NR. The pres-ence of this species was often obtained by the presence of scratch marks on large hollow bearing smooth barked gums. Large hollow bearing trees provide refuge sites for this goanna.

Lesueur's Frog *Litoria* sp. affin. *lesueuri* and Booroolong Frog were only detected beside creeks that had rocky areas (riffle zones) within and beside them. Lesueur's Frog *Litoria* sp. affin. *lesueuri* and Booroolong Frog call while stationed on rocks. Lesueur's Frog lay their eggs on submerged rocks and Booroolong Frog lay their eggs within narrow spaces between rocks (Daly *et al.*, 2001).

Constructed habitat such as dams were utilised by Ewing's Tree Frog *L. ewingii*, Peron's Tree Frog *L. peroni*, Common Eastern Froglet *Crinia signifera* and Pobblebonk *Limnodynastes dumerilii* for breeding.

DISCUSSION

Factors influencing the distribution of reptiles on the south-west slopes.

The distribution of reptiles may indicate habitat linkages through either a common substrate and/or vegetation community (Daly, 2000). Distribution data (Swan *et al.*, 2004) indicates that certain species (eg Heatwole's Water Skink *Eulamprus heatwolei* and Gippsland Water Dragon *Physignathus lesueurii howitti*) have colonised the more mesic portions (Woomargama NP) of the south-west slopes via linkages with the Kosciuszko range. To the west of Woomargama NP lies the relatively drier Tabletop NR and adjoining Benambra NR. Nobbi-Dragon *Amphibolurus nobbi* and Carnaby's Skink *Cryptoblepharus carnabyi* occur at these sites and were not observed in the more mesic Woomargama NP. Annual precipitation and the resulting vegetation communities have an influence on the distribution of reptiles.

The presence of several species of reptile represents extensions to their currently known range. Lemckert (1998) and Annable (1995) did not record Nobbi Dragon in the region. Swan *et al.* (2004) only recorded a few Nobbi

Table 6. Distribution of observations of lizards in different microhabitats.

N = number of observations

Species		Under Rock	On Rock	Under Log	On Log	In Log	Under Bark	In Litter	N
Amphibolurus nobbi	Nobbi Dragon	0	0	0	2	0	0	0	2
Pogona barbata	Bearded Dragon	0	0	1	0	0	0	0	1
Christinus marmoratus	Marbled Gecko	5	0	0	0	0	16	0	21
Diplodactylus intermedius	Eastern Spiny-tailed Gecko	4	0	0	0	0	0	0	4
Diplodactylus vittatus	Stone Gecko	8	0	1	0	0	0	0	9
Underwoodisaurus milii	Thick Tailed Gecko	1	0	0	0	0	0	0	1
Carlia tetradactyla	Southern Rainbow Skink	6	0	2	0	0	0	22	30
Cryptoblepharus carnabyi	Carnaby's Skink	0	0	0	7	1	0	0	8
Ctenotus robustus	Striped Skink	1	0	0	0	0	0	6	7
Ctenotus taeniolatus	Copper-tailed Skink	31	0	1	0	0	0	2	34
Egernia cunninghami	Cunningham's Skink	6	0	0	0	0	0	0	6
Egernia striolata	Tree Skink	28	15	0	6	14	3	1	67
Eulamprus heatwolei	Heatwole's Water Skink	0	18	1	21	0	0	0	40
Hemiergis decresiensis	Three-toed Skink	5	0	8	0	0	0	0	13
Lampropholis delicata	Grass Skink	0	0	2	0	0	0	0	2
Lampropholis guichenoti	Garden Skink	1	0	12	3	0	0	66	82
Lerista bougainvillii	Bougainville's Skink	0	0	2	0	0	0	1	3
Morethia boulengeri	Boulenger's Skink	12	0	24	8	0	0	4	48
Tiliqua scincoides	Eastern Bluetongue	1	0	0	0	0	0	0	1
Totals		109	33	54	47	15	19	102	379

Dragon from the study region. Other species recorded outside their known distributions include Bearded Dragon *Pogona barbata* (Mudjarn NR), Carnaby's Skink (Ellerslie NR, Tabletop NR and Albury), Boulenger's Skink *Morethia boulengeri* (Mudjarn, Tumblong and Ellerslie and Albury) and Yellow-faced Whip Snake *Demansia psammophis* (Ellerslie NR). The banded (Bells) form of Lace Monitor *Varanus varius* was observed at Benambra NP. This form is normally found north of the study area (Cogger, 2000).

Significance of microhabitat components for reptiles

Evidence from this and other studies (Goldingay *et al.*, 1996, G. Daly, unpub. data) indicate that ground cover, rocks, logs, litter and the presence of mature trees (hollows and decorticating bark) are important habitat components for reptile diversity.

Catling and Burt (1995) devised a numerical system to measure habitat complexity by tallying independent scores for habitat components. This system has been used to relation to small mammals and avifauna but not reptiles. Data from this study indicates that such a numerical system would be useful in ranking habitat for reptiles. However, based on the results of this study such a system should include rock outcrops as a habitat component.

Threatened and Regionally Significant Species

The Booroolong Frog *Litoria booroolongensis* is currently listed on Schedule 1 of the NSW Threatened Species Conservation Act (1995) was observed at Journama Creek, a tributary of Blowering Dam. Blowering Dam contains several species of exotic fish that include Plague Minnow *Gambusia holbrooki* (pers. obs), Trout *Oncorhynchus mykiss* and *Salmo trutta* and Redfin *Perca fluviatilis* (B. Deas pers. comm.). These species of fish have been recorded feeding on frog eggs and/or tadpoles (Gillespie and Hero, 1999). The presence of exotic fish in many of the creeks on the south-west slopes is a concern for all riverine species of frog including the Booroolong Frog.

The Inland Carpet Python *Morelia spilota metcalfei* was not found during the survey. Anecdotal evidence from long term residents (farmers) indicated that Inland Carpet Pythons were seen more frequently prior to about 1980 when rabbits were abundant. The decline of rabbits from pathogens, ripping and gassing of warrens has probably had an impact on Inland Carpet Python by loss of a prey species. Pythons can take refuge in rabbit warrens and unintentional mortality may also have occurred during rabbit control operations.

One animal from the family Pygopodidae was found during the survey. The Olive Legless Lizard *Delma inornata* was found under a sheet of iron. Other species of legless lizard known to occur in the study area include the Scaly Foot *Pygopus lepidopodus* and Burton's Legless Lizard *Lialis burtonis*. However, there are few records of these species in this region (see Swan *et al.*, 2004). There is no data on the historic relative abundance of these species and the current and previous surveys suggest that these species are regionally rare.

Conservation management strategies

The bulk of the study was part of a broader fauna survey conducted for the New South Wales National Parks and Wildlife service to assess the species diversity of lands, which have recently come into the reservation system. The study indicated the need to acquire additional lands to link currently isolated blocks of native vegetation. Many of the species of reptiles were found to have specific habitat requirements that were linked to native vegetation. The large-scale clearing that has occurred in the region for agriculture has left many species confined to isolated islands of bush.

To cater for a broad array of species habitat corridors should cover riparian and ridgeline habitats. Rock outcrops often have a higher reptile species diversity than the surrounding

rock free land and should be given preferential treatment when considering land for acquisition.

Large areas of the agricultural land in the region were affected by salt and remnant vegetation often showed signs of salt induced dieback. Many trees were also suffering from insect induced dieback (insects eating new growth) and lerp attack. Timber is removed from freehold land for fuel. The loss of hollow bearing trees from dieback and fallen timber will further reduce the habitat within a region that is highly fragmented. The woodland ecosystems in temperate south-eastern and southwestern Australia have been the most affected by vegetation clearance (Saunders, 1997). Previous clearing and current habitat loss have impacted on the species diversity and density of herpetofauna in the region. Unfortunately the lack of quantitative data on herpetofauna makes the rate of change impossible to evaluate. The general lack of information on the general distribution of herpetofauna also makes it difficult to assess the impact of habitat loss on regionally rare species.

To help conserve biodiversity there is an urgent need to retain key habitat components over the various land tenures. Local governments should work in concert with Landcare groups to encourage landowners to fence creeklines, enlarge the road easements so that additional forested land is protected and revegetate much of the landscape. The provision of waste logs, stumps and rocks within these corridors would enhance habitat complexity. There is also a need to conserve habitat on freehold land through voluntary conservation agreements. This will hopefully enable land between conservation reserves to be retained or facilitate the regeneration of native forest.

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APPENDIX A. LOCATION OF SURVEY SITES

R = ridge, M = midridge, G = Gully, NP = National Park, NR = Nature Reserve, Eastings and Northings are in Australian Map Grid reference, Altitude in metres.

Table 1. Sites searched for reptiles.

Site No.	Site Name	Map	Easting	Northing	Altitude
M1	Ulandra NP	Junee	583100	6150900	440
M2	Ulandra NP	Junee	585600	6149400	500
M3	Ulandra NP, off Ulandra trig Rd	Junee	582600	6147200	540
M4	Ulandra NP, near dam	Junee	584800	6143800	540
R1	Ulandra NP, Radio tower	Junee	582500	6146500	760
G1	Ulandra NP	Junee	581500	6147900	520
R2	Ulandra NP, Ulandra old homestead	Junee	582500	6150600	440
R1	Livingstone NP	Big Springs	531800	6086050	440
R2	Livingstone NP	Big Springs	530900	6086700	460
G1	Livingstone NP	Mangoplah	533300	6084100	400
G2	Livingstone NP	Big Springs	533100	6086100	400
M1	Livingstone NP	Big Springs	532200	6085300	450
M2	Pullentop NR	Nest Hill	533950	6069600	450
R1	The Rock NP	The Rock	506700	6096500	500
R1	Benambra NP	Mountain Creek	507230	6039980	620
R2	Benambra NP	Mountain Creek	507620	6037250	580
M1	Benambra NP	Mountain Creek	509400	6041980	360
M2	Benambra NP	Mountain Creek	510160	6040570	330
G1	Benambra NP	Mountain Creek	508820	6040100	350
G2	Benambra NP	Mountain Creek	507960	6040770	390
G1	Weisners Swamp NR	Walbundrie	481600	6052500	200
R1	Woomargama NP	Lankeys Creek	553170	6033810	723
R2	Woomargama NP	Lankeys Creek	551860	6032500	775
M1	Woomargama NP	Lankeys Creek	549655	6032500	752
M2	Woomargama NP	Lankeys Creek	548780	6033040	728
M3	Woomargama NP	Lankeys Creek	574580	6032070	672
M4	Woomargama NP	Lankeys Creek	546415	6032155	676
G1	Woomargama NP	Lankeys Creek	554720	6034730	600
G2	Woomargama NP	Lankeys Creek	552880	6031710	700
R1	Woomargama NP	Narra Narra	544747	6030530	540
R2	Woomargama NP	Narra Narra	544076	6030744	600
G1	Woomargama NP	Narra Narra	544387	6031662	590
G2	Woomargama NP	Lankeys Creek	545652	6029872	630
G3	Woomargama NP	Narra Narra	541505	6032315	580

M1	Woomargama NP	Narra Narra	542257	6031344	501
R3	Woomargama NP	Narra Narra	537142	6031250	890
R1	Tabletop NR	Mountain Creek	505880	6030880	710
R1	Mudjarn NR	Tumorrama	614778	6104217	550
R2	Minjery NR	Brungle	602213	6100818	750
G1	Mudjarn NR	Tumorrama	614710	6102620	290
G2	Minjery NR	Tumut	605313	6097532	390
M1	Mudjarn NR	Tumorrama	614040	6106100	470
M2	Minjery NR	Brungle	602220	6099760	585
R1	Ellesley NR	Yaven Creek	578710	6098710	490
R2	Ellesley NR	Yaven Creek	580350	6095878	635
R3	Tumbelong NR	Mount Adrah	589840	6103850	550
G1	Ellesley NR	Mount Adrah	579320	6101520	300
G2	Ellesley NR	Yaven Creek	581570	6099350	270
M1	Tumbelong NR	Mount Adrah	588900	6102770	575
R1	Dananbilla NR Mangles Ridge	Gunning	687600	6143700	660
R2	Dananbilla NR Easement 40	Gunning	688100	6141400	680
R3	Dananbilla NR 72/79 burn	Gunning	686500	6143100	700
M1	Dananbilla NR 96 burn	Gunning	686300	6143000	680
G1	Dananbilla NR Swamp Gully	Gunning	687500	6142500	640
G2	Dananbilla NR Southern Gully	Gunning	687000	6140800	580
R1	Williams VCA	Koorawatha	644250	6223150	620
M1	Williams VCA	Koorawatha	643900	6223200	550
G1	Williams VCA	Koorawatha	644000	6223050	540
M1	Dananbilla NR	Koorawatha	640200	6221250	500
M2	Dananbilla NR	Koorawatha	638900	6219700	430
G	Dananbilla NR, Happy Jacks	Koorawatha	639300	6220900	440
G	Boona/Cains VCA	Boorowa	649600	6201800	575
M1	Boona/Cains VCA	Boorowa	648500	6202000	610
M2	Boona/Cains VCA	Boorowa	648900	6201800	600
M3	Boona/Cains VCA	Boorowa	649100	6201150	605
R1	Boona/Cains VCA	Boorowa	648750	6204200	590
R2	Boona/Cains VCA	Boorowa	649350	6204200	605

Table 2. Frog survey sites

Reserve	Topographic map	Easting	Northing	Altitude
Mudjarn NR	Tumorrama	614710	6102620	290
Minjery NR	Tumut	605313	6097532	390

MALE RITUAL COMBAT IN THE PYGMY COPPERHEAD SNAKE (*AUSTRELAPS LABIALIS*: ELAPIDAE)

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Male ritual combat has been recorded from many genera and species of Australian elapids (Shine, 1991; Greer, 1997). It is generally observed in species where there is marked sexual dimorphism in body size; competition between males for access to receptive females being the presumed reason for this behaviour (Shine, 1978, 1991; Greer, 1997).

The pygmy copperhead, *Austrelaps labialis*, is a medium-sized elapid snake. Pygmy copperheads are sexually dimorphic in body size – snout vent length of males averages 0.48 m while females average 0.43 m (Shine, 1991). Occasionally males can grow to a SVL of 0.74 m (total 0.88 m) while females reach 0.64 m (0.76 m) (pers.obs.). The species is endemic to the Mount Lofty Ranges, the Fleurieu Peninsula, and Kangaroo Island in South Australia (Foster & Littlely, 2000).

Male ritual combat has been recorded for the two larger species of *Austrelaps, A. superbus* and *A. ramsayi* (Shine & Allen, 1980; Ehmann, 1992; Lintermans, 1992; Greer, 1997; Clemann & Saddlier, 2000). This note provides the first published records of apparent male ritual combat for *Austrelaps labialis*, providing clear evidence of ritual combat in all three species of *Austrelaps*.

On 21 March 1985 John Dallwitz, while conducting historical survey work, observed and photographed two *A. labialis* in apparent male ritual combat (Figure 1). The snakes were observed near the old Muston jetty, south west of American River (35°47'S 137°46'E) on Kangaroo Island. The behaviour was observed for a period of between 15 and 20 minutes (John Dallwitz, pers. comm.).

A second observation of apparent male ritual combat was made in early May 1993 between 11am and midday by Pru Coulls. Two *A. labialis* were observed engaged in combat, in a shed 9 kilometres north of Seal Bay (35°59'S 137°18'E) on the south coast of Kangaroo Island. The two snakes were estimated to be between 0.4 m and 0.5 m in total length, with one slightly larger than the other. They were wrapped around each other "...like the medical symbol. They were disturbed and unravelled but re-engaged". The behaviour continued for about 15 minutes. The weather was described as warm and sunny (Pru Coulls, pers. comm.).

Male ritual combat in Australian elapids, including *Austrelaps superbus*, has generally been observed in spring (Greer, 1997). Exceptions to the rule are *Austrelaps ramsayi*, *Notechis ater humphreysi* and *Notechis ater serventyi* which engage in combat from mid summer to autumn (Greer, 1997). Both observations of apparent male ritual combat for *A. labialis* reported in this paper occurred in autumn. Interestingly all observations to date of "non spring" male combat have been cool-climate closely-related species i.e. *A. ramsayi, N. a. humphreysi, N. a. serventyi* and *A. labialis*.

In addition to entwining bodies, combat in elapids usually involves close proximity of heads as each male endeavours to force the opponent's head down (Shine, 1991; Greer, 1997). Shine and Allen (1980) stated "One unusual feature of *A. superbus* combat is the tendency for only the posterior parts of the bodies to be entwined; the heads of the snakes may be quite distant from each other". Heads separated during combat was

also observed in *A. ramsayi* (Clemann & Saddlier, 2000). This appeared to be the case with the male ritual combat in *A. labialis* observed by John Dallwitz, as two of the three photographs taken clearly show the heads of the two competing males distant from each other. The two *A. labialis* in combat in the vicinity of Seal Bay also had their heads significantly apart (Pru Coulls, pers. comm.).

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Figure 1. Male combat in *Austrelaps labialis*. Photo: J. Dallwitz.

USING VISIBLE IMPLANT ELASTOMER TO INDIVIDUALLY MARK GECKOS

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Distinguishing among individuals is essential for many lizard studies, whether they be based on field populations or laboratory-kept colonies. In studies of small lizard species, the technique that is used most frequently is removing toes in unique combinations (Ferner, 1979; Dunham et al., 1994; Paulissen & Meyer, 2000). One potential problem with this marking technique is that it may affect the subsequent performance and survivorship of animals (reviewed in Dunham et al., 1994). This may especially be the case for geckos because members of this group have specialized adhesive pads on their toes that enable them to adhere to vertical surfaces and the lower side of horizontal surfaces (Autumn et al., 2000). Studies on a range of gecko species clearly demonstrate that clinging ability is positively correlated with the area of the toe pads (Irschick et al., 1996). We know of only one study (Paulissen & Meyer, 2000) that examined how toe-clipping affects gecko performance. Removing one toe per foot did not significantly affect the clinging ability of the Mediterranean gecko (Hemidactylus turcicus). However, the authors of this paper suggest that removing more than one toe per foot might reduce the gripping power of that foot enough to impair the gecko's ability to cling and to run along a wall.

Visible Implant Elastomer (VIE) is a viscous liquid that can be injected into tissue with a hypodermic syringe. This material cures into a pliable solid that serves as a cohesive, well-defined mark. The color of the elastomer facilitates visibility under normal lighting conditions, and can be further enhanced under blue LED light or with other fluorescence enhancing techniques. This tagging technique was developed by Northwest Marine Technology, Inc. for marking juvenile migratory fish for later identification. It has been used for marking other aquatic or partly aquatic organisms, such as juvenile crustaceans and larval and adult anurans (reviewed in Penney et al., 2001; Davis & Ovaska, 2001). Penney et al. (2001) report VIE as a safe, reliable, easy to use, and cost effective method for marking a terrestrial sand skink (Neoseps reynoldsi). VIE is also a potentially suitable marking technique for geckos but this application has not been examined.

We injected VIE to individually mark Lesueur's velvet gecko (Oedura lesueurii). Our main purpose for unique identification was to distinguish among geckos after laboratory experiments that involved placing two or more animals together in the same arena. Geckos were returned to the field at the end of our study. We chose not to remove toes because we needed to accurately measure the locomotor performance of animals (Dodd, 1993). Additionally, velvet geckos use toe pads to cling onto sandstone rocks, and this ability may be important for thermoregulation (Kearney, 2001). Using Passive Integrated Transponder tags may be feasible for adults (60 mm snout-to-vent length), but is impractical for marking immature animals because of their small size (< 20 mm SVL at hatching). Sewing beads into the base of the tail (Leuck, 1993) or branding (Clark, 1971) are likewise precluded by the difficulty of finding implements small enough to mark immature geckos without seriously harming them. Painting with small bands or spots of colored paint can be used on all sizes of geckos, but the marks are lost several times a year through shedding. The dorsal patterns of individuals are superficially different, but do not vary enough to enable rapid identification.

In the laboratory we tested both the safety and reliability of tag retention, and the effect

of marking on the growth rates of juvenile geckos. To prepare for injection, we mixed 10 parts elastomer with one part curing agent, stirred for one minute, and injected about 0.1 cc of this mixture into the back of a 0.3 cc insulin syringe with a 1 cc syringe. With one hand, the lizard was restrained such that its ventral side was oriented upwards in the hand; the gecko's upper body was held firmly between the index and middle fingers and the thumb pinned its lower body to the ring finger. The other hand was used to insert the needle under the ventral surface of the gecko's skin, and a drop of elastomer was injected using the 0.3 cc syringe. Elastomer was injected into the ventral side of the gecko's body to allow visual identification of markings without the use of LED light or other fluorescence enhancing techniques. Such visual identification through naked eyes is useful to reduce handling time, thereby reducing any possible stress on animals. If the injection were not subcutaneous the tag would always smudge onto the outer surface of the gecko's skin and be removed during shedding.

There are currently five different colors of elastomer that fluoresce. A simple formula can be used to determine the number of potential unique marks available given certain combinations of elastomer colors, marking locations and tags per individual (http://www.nmt-inc.com/Products/VIE/vie.htm). For example, the number of unique codes with two tags per individual can be determined using: $L \times (L-1) \times C^2 /2$, where C = the maximum number of colors per individual, and L = the number of body locations. In adult geckos we injected elastomer at 12 possible locations, and in juvenile geckos we injected elastomer at nine possible locations (Figure 1). We used pink and green elastomer and two tags per individual, which yielded 264 possible unique combinations for adults and 144 possible unique combinations for juveniles. We uniquely marked 195 individuals (55 adult males, 69 adult females and 71 juveniles) with this technique. All marked geckos were maintained in the laboratory for four months post-tagging. During this time they were individually housed in plastic cages (12 x 20 x 10 cm) under standard animal husbandry protocols and periodically used in laboratory experiments. We scored the retention of the tags two days, two months and four months after injection. On most individuals we used the naked eye to detect tags, but a UV lamp was used to improve the visibility of marks on some heavily pigmented geckos. We also measured the SVL and mass of juveniles at the time of marking and three months afterwards.

After two days, the retention of elastomer tags was 100%. Two months after injection elastomer tags were retained in 50 of the 55 marked adult males, 65 of the 69 marked adult females, and 69 of the 71 marked juvenile geckos. After four months, all marked animals from the two month census retained tags. During this period, the rate of mortality of injected animals was less than 0.01%. The marks of a small number of geckos (five adult males, 13 adult females, six juveniles) moved to within 1.5 mm of the initial position. Mark migration was also reported in sand skinks and was suggested to reflect growth of the individuals (Penney et al., 2001). In the present study the highest rates of mark migration were in adult female geckos and probably reflect movement after egg deposition; animals were marked while gravid and re-checked after oviposition. During the three months following marking, there was no significant difference in growth rate of juveniles that were tagged versus not tagged (MANOVA with SVL, weight, and weight/SVL as a factor: df = 3,75, F = 1.50, P = 0.22).

Our results suggest that geckos should be included in the range of taxa in which injecting VIE is a useful marking technique. The tags uniquely identify individuals, are easily discernable, and are unlikely to cause excessive pain or discomfort to the animals. Our tags were retained for at least several months after injection. In a few cases tag loss was reported but this inaccuracy is also evident when marking animals, for example, by toe-clipping (i.e., due to loss of toes by natural

means). The only other study on a terrestrial lizard demonstrates that elastomer marks can be reliable for at least two years (Penney et al., 2001). Importantly, injection did not affect survivorship of geckos or rates of growth in juveniles. Since the tags are administered on the ventral side of the body, they are unlikely to enhance an animal's visibility to predators (see Anholt et al., 1998; Malone et al., 1999). Once the skill of injecting is learned, one person can readily implant elastomer tags. However, we expect that cooling animals before tagging will not only reduce the stress to individuals but also will increase the accuracy of the mark (Hoefer et al., 2003). Our study was restricted to a laboratory situation, but previous studies suggest that elastomer tags can easily be administered in the field (Davis & Ovaska, 2001). Using a scheme with 12 locations, two injections per animal, and five colors will yield more than 1500 possible unique combinations. In animals that can be externally sexed, the number of individual markings may be doubled. Additionally, visibility of VIE can be enhanced by LED light or with other fluorescence enhancing techniques. The relatively transluscent venter of geckos is an advantage to using this method but the technique has worked on skinks (Penney et al., 2001) and may be useful on other reptiles.

VIE is also relatively cost-effective compared with other systems such as PIT tagging (Downes, 2000; see also Penney et al., 2001). Two types of starter VIE kits are available, and both include mixing and injecting supplies, a LED flashlight, amber filter glasses, a field carrying case, an instructional video and written instructions. VIE hand injectors can be used to facilitate the use of small syringes. The "master" kit costs US$1150 and contains two hand injectors and 15 cc of elastomer in each of four colors, whereas the "four color" kit costs US$495 and contains one hand injector and 5 cc of elastomer in each of four colors. However, we did not utilize any of the items in either of these kits. Instead, we purchased a refill kit containing 5 cc of each of four elastomer colors for US$285, and used our own mixing and injecting supplies. If our marking scheme was used this quantity would allow at least 1000 individuals to be tagged. Trial packs including 2 cc of elastomer and mixing and injecting supplies are available for US$40.

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Figure 1. The potential marking positions on the ventrum of adult and juvenile geckos. Adult geckos were injected in one of 12 possible locations, and juveniles were injected on one of 9 possible locations.

Adult   ## Juvenile

ENCOUNTERS BETWEEN EASTERN BROWN SNAKES (*PSEUDONAJA TEXTILIS*) AND CANE TOADS (*BUFO MARINUS*) IN NORTHERN NEW SOUTH WALES

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INTRODUCTION

Cane toads (*Bufo marinus*) were introduced into Australia in 1937 as a means to control beetle pests of sugar cane (Lever, 2001). Since then, they have spread from their initial release points to encompass more than 50% of Qld. Toads are still expanding their range into the NT and northern NSW and are predicted to occupy an eventual area of approximately 2 million km^2 (Sutherst *et al.*, 1995).

Toads are highly toxic and as such constitute a dangerous meal for many terrestrial predators. Anecdotal reports indicate declines in predators such as snakes, goannas and quolls following the arrival of toads (Covacevich & Archer, 1975; Burnett, 1997). A recent estimate based on geographic distribution and dietary preferences of Australian snakes suggests that as many as 50 species of snake may be at risk of impact from the toad (Phillips *et al.*, 2003).

Here we report three separate incidents of Eastern Brown Snakes (*Pseudonaja textilis*) encountering a toad. To our knowledge, only one other report of such an occurrence appears in the literature. In this case, a *P. textilis* was found dead with a toad in its gut (Covacevich & Archer, 1975). All cases are from northern NSW in areas where toads have been present for less than 30 years.

OBSERVATIONS

Case 1

On the morning of 11.1.2002, Jeff Hayter found a juvenile *P. textilis* (male, SVL 620 mm, weight 70 g, gape width 15.2 mm) dead on the back steps of a property in Broadwater,

northern NSW. The body was inspected by one of us (BP) approximately 45 minutes later. The body was very fresh and there was no sign of rigor mortis. Inspection revealed the bulge of a freshly ingested prey item approximately 200 mm behind the head. This was palpated out of the animal (Fig. 1) and proved to be a small *B. marinus*, still intact and showing almost no signs of digestion (Fig. 2). The toad weighed 3 g and had a head-width of 12.9 mm. Dissection of the snake revealed no internal injuries or macroparasites. The proximate cause of death was thus assumed to be poisoning following the ingestion of the toad. Phillips *et al.* (2003) provides an index of susceptibility to toad toxin for ten species of Australian snake, including *P. textilis*. This index expresses the lethal dose as a percentage of the snake's gape-width that a toad's head-width (of sufficient size to kill the snake) represents. For *P. textilis* it was found that a toad whose head-width is only 37% of the snake's gape-width is sufficient to provide a lethal dose. In the case reported here, the ratio of toad head-width to snake gape-width (85%) places this toad well above the minimum size required to provide a lethal dose of toxins to this snake.

Case 2

On 1.3.1994, at Upper Cooper's Creek, northern NSW, Suzanne Ulyatt encountered a brown snake moving under a chair in a carpet-floored shed on the property. Returning with her husband Rick they discovered an adult toad estimated to be around 125 mm in length in the middle of the shed floor. The snake had moved into a cupboard in the corner of the shed and stayed there for some minutes before returning toward the toad.

The snake then went into convulsions, writhing for several minutes before dying. After death the snake was noticed to change colour from a mid-brown to a darker grey-brown.

On close inspection the toad proved to be paralysed but alive, being unable to move its hind limbs and was euthanased. The snake was retained and frozen. Inspection showed the snake to be an adult male *P. textilis* of 1.18 m SVL. The gut was empty and there were two old lesions on the ventro-lateral surface. While the brown snake in this case was not seen to bite the toad, the symptoms of violent convulsion are similar to those observed by the authors in snakes that have ingested or mouthed *B. marinus*.

Case 3

Another report of a *P. textilis* attacking a toad was received in January 1998 from the Possum Creek area in Byron Shire, NSW. In this case the snake was observed to bite and constrict the toad in an apparent attempt to consume it; however the ultimate fate of the animals was not discovered.

DISCUSSION

The Eastern Brown Snake (*Pseudonaja textilis*) is reported to feed mainly upon "small mammals and reptiles" (Cogger, 2000) and "lizards, mammals and birds" (Wilson & Knowles, 1988). From his analysis of gut contents in museum specimens, Shine (1991) reports the diet of this species to be comprised of "reptiles, 49%; mammals, 39%; frogs, 9%; birds, 2%; and reptile eggs, 1%".

In assessing the impact of *B. marinus* in native ecosystems, concern has generally been directed toward those snakes known to feed primarily upon frogs, e.g. the Red-bellied Black Snake (*Pseudechis porphyriacus*).

These two cases show that wild *P. textilis* do consider toads as food items and thus suffer mortality associated with the presence of toads. *Pseudonaja textilis* shows an ontogenetic shift in prey preference from ectothermic to endothermic prey (Shine, 1989). Thus, small *P.*

textilis are more likely to consider toads a prey item and may face higher rates of mortality from toads than the species' average frog consumption (of 9%) otherwise suggests.

Alternatively, if the figure of 9% simply indicates a willingness by this species to eat frogs when they are encountered (but a low encounter rate), all individuals may consider toads a suitable prey item. If consumption of a single, small toad is enough to kill the snake (as indicated here), then mortality due to toads may well be high across the entire population.

In the authors' experience however, *P. textilis* has steadily increased in abundance in coastal far northern NSW (Tweed, Byron and Lismore areas), while the Red-bellied Black snake has appeared to decline in some of these areas, wherever *Bufo* is found.

ACKNOWLEDGMENTS

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Figure 1. Eastern Brown Snake (*Pseudonaja textilis*) from Broadwater, northern NSW, found dead after swallowing a Cane Toad.

Figure 2. Closer view of ingested cane toad showing limited digestion.

NOTES ON POORLY KNOWN NEW GUINEA FROGS. I. MICROHYLIDS FROM THE D'ENTRECASTEAUX ISLANDS

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INTRODUCTION

Amphibian diversity and endemism in New Guinea and associated islands is high (Zweifel & Tyler, 1982; Allison, 1993, 1996), with many species having very restricted distributions. As a result, many Papuan frog species remain known only from type series, and basic biological information is lacking for most. Several species of frogs have hitherto been known only from Goodenough Island, D'Entrecasteaux Islands, off the southeastern tip of New Guinea. *Oreophryne inornata* and *O. insulana* were described by Zweifel (1956) from a location at 1600 m in the centre of that island (Brass, 1956); the former was described on the basis of 17 specimens, the latter from nine. A third species, *Copiula minor*, was described by Menzies and Tyler (1977) on the basis of two specimens taken at 1600 m on Oya Madawa. The first two species were based on material obtained in October, 1953 by the Fourth Archbold Expedition (Brass, 1956); the last on material collected by J. Menzies in December 1975. These species have seldom been mentioned in the literature since their original description. In the descriptions of each of these species, relatively few data were presented on morphological variation, either because sample sizes were small or because most morphological features relevant to current microhylid systematics were not discussed.

During biotic surveys in Milne Bay Province, we were able to obtain additional material for the three microhylid species mentioned above that expand knowledge of their morphological variation, geographic ranges, habitats, and other relevant ecological data. These collections come from the northern slope of the Cloudy Mountains, the southernmost mountain mass on New Guinea; from the southern slope of Oya Waka, one of the highest peaks in the western mountain massif on Fergusson Island; and from the eastern slope of Oya Tabu (Mt. Kilkerran), in eastern Fergusson Island, the highest point on that island. Our expanded understanding of these species suggests that they are not endemic to Goodenough Island, although the two *Oreophryne* species seem likely to be endemic to the D'Entrecasteaux Islands.

MATERIALS AND METHODS

Specimens were collected under all relevant national and provincial permits, anesthetized in the field, fixed in 10% formalin, and transferred to 70% ethanol for permanent storage. All measurements were made with digital calipers or an optical micrometer to the nearest 0.1 mm, with the exception that disc widths were measured to the nearest 0.05 mm. Measurements, terminology, and abbreviations follow Zweifel (1972, 1985) and Kraus and Allison (2001, 2003): body length from snout to vent (SV); tibia length from heel to skin fold of knee (TL_{fold}); tibia length from heel to outer surface of flexed knee (TL_{knee}); diameter of eye (EY); distance from anterior corner of eye to centre of naris (EN); internarial distance, between centres of external nares (IN); distance from anterior corner of eye to tip of snout (SN); head width at widest point, typically at the level of the tympana (HW); head length, from tip of snout to posterior margin of tympanum (HL); tympanum diameter (TY); hand length from proximal edge of palm to tip of 3rd finger (HandL); foot length from proximal edge of sole to tip of 4th toe (FootL); width of the third finger disc ($3^{rd}F$); width of the fourth toe disc ($4^{th}T$). The two different measurements of tibia length were given because usage has changed in the literature over time. Measurements from the skin fold at the knee are necessary to allow comparisons with original descriptions, but measurements from the outer surface of the flexed knee are more reliable and to be preferred (Kraus & Allison, 2003).

We measured egg size (capsule diameter) in mm for *Oreophryne inornata*.

Morphological comparisons were made using t-tests and Mann-Whitney Rank Sum tests (when normality or equal-variance assumptions were not met) available in SigmaStat©, version 2.0.

We recorded calls in the field using a Sennheiser K6 microphone and a Sony Professional Walkman WM-D6C cassette recorder. Call structure was analyzed using the computer programs AviSoft-SASLab Pro (v4.2) from the Sound Analysis and Synthesis Laboratory (www.avisoft-saslab.com).

SPECIES ACCOUNTS

Oreophryne inornata Zweifel, 1956

Morphology

Variation in our samples of *Oreophryne inornata* is moderate (Table 1), but expands considerably on that noted in the original description (Zweifel, 1956). Sexual differences in snout-vent length and in morphological ratios could not be detected in our samples, although that may reflect low statistical power resulting from our small sample of females.

Little important variation was evident between our samples from Oya Tabu and Oya Waka (Table 1), although ratios differed significantly between those two localities for IN/SV ($t = 2.172$, df = 52, $p = 0.034$), EN/IN ($T = 226.500$, $p = 0.008$), and EY/SN ($t = 2.056$, df = 52, $p = 0.045$). Insufficient data are presented in Zweifel (1956) to allow comparison of our Fergusson Island samples with that from Goodenough Island for any characters other than TL$_{fold}$ and $3^{rd}F/4^{th}T$. Our range and mean for the former character are identical with those reported for Goodenough Island *O. inornata* (Zweifel, 1956); our range for $3^{rd}F/4^{th}T$ (0.95-1.10) is within that presented in the original description (0.85-1.17), and our mean (1.02) is similar (1.03).

In life, specimens have either a smooth or a slightly granular appearance to their dorsal surfaces (Fig. 1A, B).

Sex Ratio

The sample taken from Oya Tabu consists of animals collected from daytime refugia during a drought; consequently, they might be expected to provide a relatively unbiased estimate of sex ratio in that population. Of our sample of 41 animals, nine are female and 32 are male, suggesting either a highly skewed sex ratio among adult *O. inornata*, differential mortality of females during drought, or a preference by females for refugia undiscovered by us.

Colour in life

Most adult animals were uniform orange-tan or yellow-tan above and pale yellow below with an orange wash under the shank (Fig. 1A); however, a few adults have obvious brown mottling (Fig. 1B). Juveniles are darker, typically being sepia above, with dark brown shoulder and interocular markings, and have light gray venters with only a little yellow colouring under the arms and legs. These brown colours fade to orange-tan or yellow-tan as the animals grow, and small adults will often be predominately tan with a few small vague areas of darker brown.

Field notes for BPBM 16217 state: "Dorsum yellow-orange with irregular brown scapular triangles with apices pointing mediad and brown triangle between eyes and pointing posteriorly, creating a rough yellow-orange X on the back. Posterior surfaces of thighs darker orange-brown. Venter lemon-yellow, deepening to orange-yellow under legs. Iris gold." BPBM 16218 was similar but the dorsum was uniformly light orange-brown and the groin and undersides of the lower legs were orange. BPBM 16239 was also similar but the brown dorsal markings were broken and obscure.

Call

On Oya Tabu, frogs were heard calling both day and night, but in all instances calling was infrequent and insufficiently vigorous to allow tracking of individuals. In all circumstances, frogs were heard calling from refugia in

bamboos or in undetermined locations in cloud forest. On Oya Waka, specimens were only found while calling in a full-throated chorus at night after a heavy rain. As is typical for the genus, they were calling from elevated perches ranging in height from 2 m up into the canopy.

We obtained recordings from five individuals (Table 2). The call (Fig. 2) consists of a single pulsed note that averages 26 ms in duration and resembles a nasal "quack" to the human ear. The dominant frequency averaged 2180 Hz and ranged 2050-2450 Hz. Calling males generally produced upwards of 20 calls at 2-7 second intervals, were quiet for a brief period (~ 20-50 s), and then resumed calling.

Reproduction

We obtained five egg clutches of *Oreophryne inornata* on Fergusson Island and this provides us with the first reproductive data for the species. All clutches were found within the hollowed centres of standing, dead bamboo stems. These locations served as moist refugia relative to most other available habitats in the forest at that time. For four of these clutches, the attendant parent was captured and, in each case, proved to be male. This is consistent with other observations for the genus (van Kampen, 1923; Zweifel, 1956; Johnston & Richards, 1993) although Zweifel (1956) also noted the occasional joint presence of a female and a male with a clutch.

Clutch sizes ranged 10-22 eggs; egg size ranged 3.5-7.9 mm and generally increased in size as the eggs developed (Table 3). Embryos were readily assigned to the 15-stage developmental table of Townsend and Stewart (1985) for *Eleutherodactylus coqui*, although we note that we never observed endolymphatic calcium deposits in *O. inornata* embryos, and stage 8 embryos had digits visible on the hands as well as feet. Most of clutch 5, collected at stage 15, hatched before we could preserve the sample. Hatchlings retain a clear tail approximately one-third to one-half the length of the body. Hatchlings were slightly greater

than 7 mm in SV length but could not be precisely measured because, when preserved, they retained the curled position maintained during embryonic development.

It is noteworthy that we could find clutches at all stages of development synchronically and that the drought that gripped Fergusson Island during the time of our visit did not prevent the frogs from continuing to breed, as evidenced by the presence of early-stage egg clutches among our samples.

Habitat

The habitat of *Oreophryne inornata* was varied. On Oya Tabu, specimens were found from 1330 m to the top of the peak at 1830 m. At the lowest site, specimens occupied an extensive bamboo grove. Above this grove, habitat consisted of a fairly open forest association dominated above 1550 m by *Metrosideros* sp. and generally having a canopy height of 10-15 m. Understory was virtually absent in the bamboo grove but consisted of dense layers of scrambling bamboo, orchids, and moss in the upper reaches of the peak. The forests in the study site are classed as lower montane in Paijmans (1975, 1976); the forests near the top of the peak are not demarcated on the vegetation map but would generally be classed as montane forest (Paijmans, 1975) or cloud forest (Mueller-Dombois & Fosberg, 1998).

On Oya Tabu, specimens were not found or heard below 1330 m even though apparently similar bamboo groves occurred as low as 1050 m. On the southern slopes of Oya Waka, in western Fergusson Island, frogs occurred at lower elevations, being found in small-crowned lowland hill forest (Paijmans, 1975, 1976) with a 25-m canopy at 980 m.

Our specimens were taken during a drought and we experienced only three nights of rain in four weeks of collecting. On Oya Tabu, specimens occupied the cavities of dead bamboo stems, occurring anywhere from a few cm below ground level to 3m above ground. Specimens most often occurred singly but in several instances aggregations of 2-4 animals occupied a single bamboo cavity. Generally, specimens occurred in cav-

ities retaining at least some moisture, but this was not invariant. At higher elevations, specimens were also found in holes in standing dead wood and in ant plants (*Hydnophytum*). Zweifel (1956: 31) previously reported the species from a variety of sites ranging from under a tree root to the limbs of trees.

Other microhylids found sympatrically with *Oreophryne inornata* include *Austrochaperina palmipes*, *Callulops robusta*, *Cophixalus ateles*, *C. verrucosus*, *Cophixalus* sp. nov., *Copiula oxyrhina*, *Hylophorbus* sp., and *Oreophryne insulana*.

Range

Our specimens came from 1330-1830 m on the eastern slope of Oya Tabu (Mt. Kilkerran), on the eastern side of Fergusson Island and from 980 m on Oya Waka, on the western side of the same island (Fig. 3). The 1830 m site is the highest point on the island. The species was previously reported only from 1600 m (Zweifel, 1956). Our localities represent range extensions of approximately 40 and 70 km ESE from the type locality for the species on nearby Goodenough Island. Elevations appropriate for this species also occur on Normanby Island and it is likely that the species will eventually be found there. Closely related species occur on mainland Milne Bay Province, so this species is likely to be a D'Entrecasteaux Islands endemic.

Oreophryne insulana Zweifel, 1956

Morphology

Variation among the five adults of our Fergusson Island sample is slight (Table 4). As for *Oreophryne inornata*, insufficient data are presented in Zweifel (1956) to allow comparison of our sample with that from Goodenough Island for any characters other than TL$_{fold}$ and 3rdF/4thT. Variation in relative leg length for our sample is within the range noted in the original description (TL$_{fold}$ = 0.37-0.40, Zweifel, 1956). Variation in 3rdF/4thT for our sample (1.00-1.44) has a broader range but smaller magnitude than that reported by Zweifel (1956) for specimens from Goodenough Island (1.30-1.64).

Important ontogenetic changes in relative sizes of several morphological features are suggested by data from our two juvenile specimens (Table 4). Tibia length, internarial distance, and eye diameter all appear of relatively greater size in our sample of juvenile frogs compared with adults. In contrast, eye-naris distance, tympanum width, and width of finger discs all appear relatively larger in adults (Table 4). The contrast in snout shape between adults and juveniles is especially pronounced if EN/IN is considered (Table 4) because the two constituent measures of this ratio change in opposite directions between juveniles and adults.

In life, specimens have a decidedly rugose appearance to their dorsal surfaces (Fig. 1C).

Colour in life

All adults had an orange ground colour, heavily blotched with dark brown markings (Fig. 1C). Field notes for BPBM 16546 state: "Dorsum orange-brown with numerous dark brown/black flecks, two large black spots above scapulae, lumbar ocelli, and black anal patch. Iris silvery gray veined with black. Side of face dark brown with orange-brown and white flecks. Sides dark brown, heavily flecked with silvery white. Venter purple-gray with numerous bluish-white flecks and some orange flecks on belly and under thighs. Groin and undersides of tibiae and tops of feet largely orange." BPBM 16547 was noted to be similar but with the dorsal black pigment more finely dusted instead of flecked.

Call

No individuals were heard calling, probably because of drought conditions prevailing during our visit.

Habitat

All our specimens came from forest shown as lower montane in Paijmans (1975, 1976) but probably more accurately classed as montane forest (Paijmans, 1975) or cloud forest (Mueller-Dombois and Fosberg, 1998) at 1720-1830 m elevation, a slight increase in known elevational range for the species, which was previously taken at 1600 m

(Zweifel, 1956). Canopy consisted largely of *Metrosideros* sp. of approximately 10 m height and the understory was dense with scrambling bamboo, orchids, and moss. This habitat descended to an elevation of 1550-1600 m, so it seems likely that *O. insulana* will range to that elevation on Oya Tabu. Trees had their trunks and limbs densely coated with deep (ca. 20 cm) moss, although, because of drought conditions, this provided no moist refuge for the frogs during our visit. All five adult frogs were excavated from small chambers in dead, standing tree trunks. One juvenile was hopping on leaf litter on the forest floor; the other was taken from within a soaked clump of sphagnum on the forest floor. Zweifel (1956: 34) previously reported the species from a variety of sites ranging from under a tree root to the limbs of trees.

We found this species to occur sympatrically with *Callulops robusta*, *Cophixalus* sp. nov., and *Oreophryne inornata*. *Cophixalus ateles* and *C. verrucosus* were found nearby at 1400-1500 m and may also occur syntopically with *O. insulana*.

Range

Our specimens came from 1720-1830 m on the eastern slope of Oya Tabu, on the eastern side of Fergusson Island (Fig. 3). The 1830 m site is the highest point on that island. This locality represents a range extension of approximately 70 km ESE from the type locality for the species on nearby Goodenough Island. We found no specimens of this species on the western massif of Fergusson Island, and only a small patch of habitat (ca. 1-2 ha) that appeared to be possibly appropriate for the species there. Given its known elevational range from 1600-1830 m, it seems unlikely that the species occurs on Normanby Island, which is lower (max. elev. ca. 1300 m). Close relatives occur on the mainland of Milne Bay Province and this species is likely to be restricted to the uplands of Goodenough Island and eastern Fergusson Island.

Copiula minor Menzies & Tyler, 1977

Morphology

Our sample (n = 13) consists entirely of adults, all but one of which are male. Variation in relative morphological measures is moderate (Table 5). Morphological ratios were not provided in the original description of *Copiula minor*, which was based on two specimens (Menzies & Tyler, 1977), but we here provide comparison with the holotype. The holotype falls within the range of morphological variation shown in our sample of *C. minor*, with the following exceptions: TL is shorter in the holotype than in our specimens (TL$_{knee}$/SV = 0.43 vs. 0.47-0.53), HL is slightly longer (HL/SV = 0.36 vs. 0.31-0.35), and the discs are noticeably smaller (3rdF/SV = 0.022 vs. 0.028-0.035; 4thT/SV = 0.032 vs. 0.042-0.051). Given these morphological differences, it might be thought that our sample represents a new species, but we include it in *C. minor* because of the close similarity in call structure (see below). It will remain uncertain whether the differences observed between the holotype and our Cloudy Mts. sample represent geographical or individual variation within *C. minor* until larger series become available from Goodenough Island.

Menzies and Tyler (1977) noted that they could find no morphological ratios that served to distinguish *Copiula minor* from *C. oxyrhina* or *C. fistulans*. We largely concur with this assessment, although we note that there are minor differences in relative leg length that separate *C. minor* to some degree from the other two species (Fig. 4).

The skin was uniformly smooth in all specimens.

Colour in life

Field notes for BPBM 15665 state: "Light orange-brown dorsally with mottling of brown; lumbar ocelli present in the form of two brown blotches. Venter light yellow-orange; undersides of limbs orange. Iris brass. Narrow brown suprascapular line continues as series of dots posterior to forearm." BPBM 15666 was similar but with the dorsum brown and undersides yellow; no orange was present. Most specimens had an orange cast to the dorsal and ventral surfaces (Fig. 1D). This served to distinguish them easily from syntopic *C. oxyrhina*, which invariably had a

wine-red cast to the dorsal surfaces (Fig. 1E) and red under the legs. We have, however, found occasional specimens of C. oxyrhina from Misima Island, the type locality for that species, to be orange (Fig. 1F), although not of the same hue as seen in C. minor.

Call

All specimens were found while calling at night from small chambers in the soil, just below its surface and usually covered by leaves. Specimens were difficult to track because they were so well hidden, but occasionally the white snout tip could be seen at the entrance to the chamber. The largest chorus was heard calling during a night with rain continuing at light to moderate levels for many hours. This sedentary, secretive calling behaviour contrasts with that of the syntopic C. oxyrhina, which called briefly from the forest floor, changed positon to a new site, and called again, switching calling location every minute or so.

We recorded vocalizations from three different individuals (Table 6). The calls from all three were similar and consisted of trills with upwards of 66 call notes and dominant frequencies that averaged about 1260 Hz (Fig. 5). The call notes averaged 3.2 ms and the intervals between calls averaged slightly longer at 3.7 ms. Call rates for the three individuals averaged 15.4 notes/s. One individual called every 30-60 seconds.

Habitat

Frogs were found in medium-crowned lowland hill forest (Paijmans, 1975, 1976) at 800 m elevation; this is an extension of the known elevational range for this species from its previous record at 1600 m (Menzies and Tyler, 1977). Canopy height at this locality was approximately 25 m, with emergents to 30+ m. This was near the lower elevation at which moss was growing on the ground. The sole population we found inhabited a narrowly circumscribed area on relatively flat land along a ridge; no other specimens were heard in the ca. 2 km of additional ridge habitat searched. Other microhylids found sympatrically with C. minor include Cophixalus ateles, C. verrucosus, Cophixalus sp.

nov., Copiula oxyrhina, Genyophryne thomsoni, Hylophorbus rufescens, Liophryne dentata, Mantophryne lateralis, and two species of Oreophryne.

Range

Our specimens came from 800 m on the north slope of the Cloudy Mountains, the southernmost mountain range of New Guinea (Fig. 3). This locality is approximately 130 km due south of the type locality on Goodenough Island and separated from it by Goodenough Bay and the southern extent of the Owen Stanley Mts. Given this considerable expansion in known range and elevational tolerance, it seems likely that C. minor will be discovered to be fairly widespread in the southern reaches of the Owen Stanley Range and on Fergusson and Normanby islands.

We note that the type locality as given in the original description (Menzies & Tyler, 1977: 441) is apparently a printer's error resulting from a transposition of letters (J. Menzies, pers. comm.). The locality in the original description is given as "Oiadamawa'a Peak", in reference to the highest peak on Goodenough Island. In fact, the name for that peak is "Oya Madawa" (or "Oiamadawa", following the spelling employed by Menzies & Tyler, 1977).

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Figure 1. Photos in life of (A) *Oreophryne inornata*, BPBM 16230, Fergusson Island; (B) *Oreophryne inornata*, BPBM 16217, Fergusson Island; (C) *Oreophryne insulana*, BPBM 16548, Fergusson Island; (D) *Copiula minor*, BPBM 15666, Cloudy Mountains; (E) *Copiula oxyrhina*, BPBM 16166, Fergusson Island; (F) *Copiula oxyrhina*, BPBM 17091, Misima Island. All photos by F. Kraus.

Figure. 2 (A) Waveform, and (B) spectrogram of a 5-call sequence of *Oreophryne inornata*, BPBM 16253, from 990 m on S slope of Oya Waka, Fergusson Island. Recorded 13.ix.2002, air temperature 17.0°C. The power spectrum is shown to the left of the spectrogram. Recording by F. Kraus.
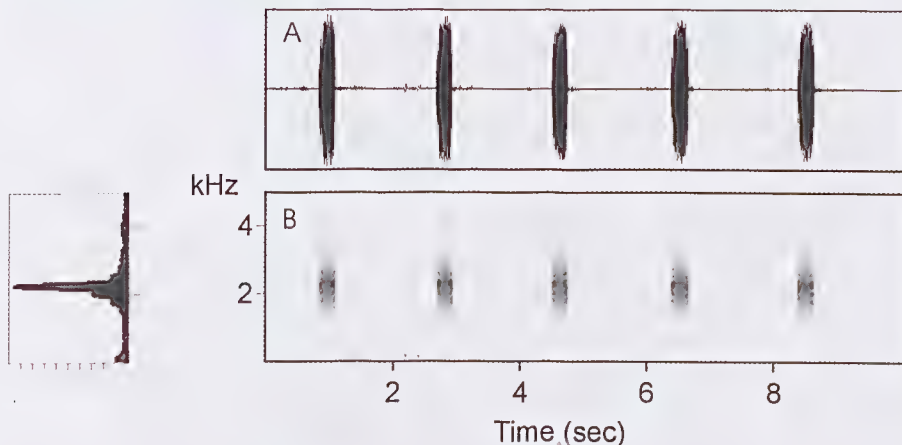

Figure 3. Map of southeastern New Guinea and D'Entrecasteaux Islands, showing collecting localities for *Oreophryne inornata* (open circles), *O. insulana* (star), and *Copiula minor* (closed circle). Stippling indicates areas of 1000 m and above.
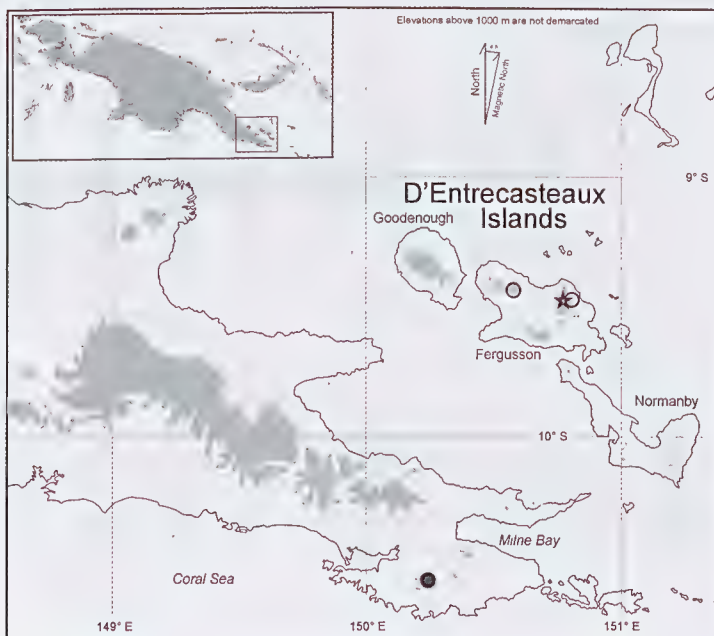
Figure 4. Comparison of relative leg length between *Copiula minor* (solid diamonds), *C. fistulans* (solid triangles), and *C. oxyrhina* (open squares).
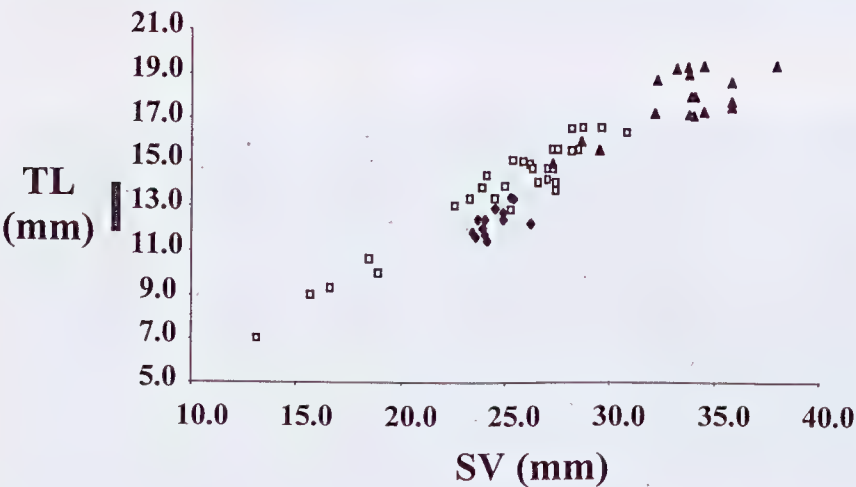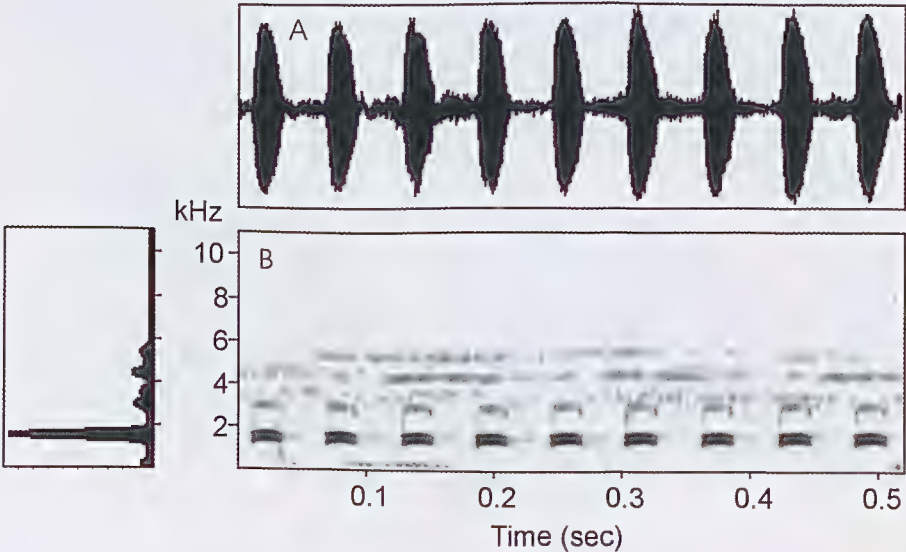

Figure 5 (A) Waveform, and (B) spectrogram of a nine-note sequence of *Copiula minor*, BPBM 15665, from 800 m near Upaelisafupi Stream, N slope of Cloudy Mountains. Recorded 2030hrs, 19.iv.2002; air temperature 21°C. The power spectrum is shown to the left of the spectrogram. Recording by F. Kraus.

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APPENDIX I

Specimens Examined

Copiula fistulans (n = 18): Papua New Guinea: Madang Prov.: Wanuma (BPBM 5710); Morobe Prov.: Oomsis, 6.6750°S, 146.8000°E, (BPBM 17324-27, 17329-37); Chimbu Prov.: Crater Mountain Biological Station, 9.6 km E Haia, 6.7239°S, 145.0926°E, 850 m (BPBM 16652-55).

Copiula minor (n = 14): Papua New Guinea: Milne Bay Prov.: Goodenough Island, Oya Madawa, 1600 m (UPNG 5435, holotype); ridge near Upaelisafupa Stream, 10.5009°S, 150.2302°E, 800 m (BPBM 15665-70, 15672-73, PNGNM 23942-45), 2 km SW Upaelisafupa Stream, 10.5095°S, 150.2224°E, 980 m (BPBM 15671).

Copiula oxyrhina (n = 30): Papua New Guinea: Milne Bay Prov.: near Upaelisafupa Stream, Cloudy Mts., 10.4971°S, 150.2330°E, 800 m (BPBM 15306-35).

Oreophryne inornata (n = 56): Papua New Guinea: Milne Bay Prov.: Fergusson Island: E slope Oya Tabu, 9.4604°S, 150.7846°E, 1330 m (BPBM 16217-39, PNGNM 23927-36), E slope Oya Tabu, 9.4574°S, 150.7764°E, 1480 m (BPBM 16240-41), E slope Oya Tabu, 9.4601°S, 150.7714°E, 1770 m (BPBM 16245), summit Oya Tabu, 9.4624°S, 150.7668°E, 1830 m (BPBM 16243), S slope Oya Waka, 9.4562°S, 150.5596°E, 980 m (BPBM 16249-56), S slope Oya Waka, 9.4484°S, 150.5592°E, 1300-1400 m (PNGNM 23937-41); Goodenough Island: E slopes, 1600 m (AMNH 57000, holotype, and 56731, 56912, 56984, 57262, 57353, paratypes).

Oreophryne insulana (n = 11): Papua New Guinea: Milne Bay Prov.: Fergusson Island: E slope Oya Tabu, 9.4601°S, 150.7723°E, 1720 m (BPBM 16119, 16548-51), summit Oya Tabu, 9.4624°S, 150.7668°E, 1830 m (BPBM 16546-47); Goodenough Island: E slopes, 1600 m (AMNH 57267, holotype, and 56915, 57265-66, paratypes).

Table 1. Morphological variation within Fergusson Island *Oreophryne inornata*. Numbers are range (mean).

Character	Males (n=44)	Females (n=10)	Oya Tabu (n=41)	Oya Waka (n=13)	Combined sample (n = 54)
SV	22.5-40.9 (31.7)	22.4-40.4 (33.0)	22.4-40.9 (31.8)	22.5-33.7 (31.2)	22.4-40.9 (32.2)
TL(fold)/SV	0.36-0.42 (0.39)	0.36-0.42 (0.39)	0.36-0.42 (0.39)	0.36-0.42 (0.39)	0.36-0.42 (0.39)
TL(knee)/SV	0.39-0.48 (0.43)	0.39-0.47 (0.43)	0.39-0.48 (0.43)	0.39-0.45 (0.43)	0.39-0.48 (0.43)
EN/SV	0.078-0.098 (0.088)	0.078-0.098 (0.087)	0.078-0.098 (0.088)	0.078-0.094 (0.087)	0.078-0.098 (0.088)
IN/SV	0.078-0.098 (0.084)	0.075-0.089 (0.083)	0.075-0.098 (0.083)	0.081-0.093 (0.085)	0.075-0.098 (0.083)
SN/SV	0.12-0.15 (0.14)	0.12-0.15 (0.14)	0.12-0.15 (0.14)	0.12-0.14 (0.13)	0.12-0.15 (0.13)
TY/SV	0.033-0.046 (0.040)	0.035-0.049 (0.041)	0.035-0.046 (0.040)	0.033-0.049 (0.040)	0.033-0.049 (0.040)
EY/SV	0.12-0.15 (0.13)	0.11-0.14 (0.13)	0.11-0.15 (0.13)	0.12-0.14 (0.13)	0.11-0.15 (0.13)
HW/SV	0.35-0.41 (0.38)	0.35-0.39 (0.37)	0.35-0.41 (0.38)	0.35-0.40 (0.37)	0.35-0.41 (0.38)
HL/SV	0.30-0.34 (0.32)	0.30-0.33 (0.32)	0.30-0.34 (0.32)	0.30-0.33 (0.32)	0.30-0.34 (0.32)
HandL/SV	0.27-0.33 (0.29)	0.27-0.31 (0.29)	0.27-0.33 (0.29)	0.27-0.30 (0.28)	0.27-0.33 (0.29)
FootL/SV	0.37-0.47 (0.43)	0.40-0.46 (0.43)	0.39-0.47 (0.43)	0.37-0.43 (0.41)	0.37-0.47 (0.43)
3rdF$_3$/SV	0.062-0.084 (0.072)	0.063-0.077 (0.070)	0.063-0.077 (0.072)	0.062-0.084 (0.071)	0.062-0.084 (0.071)
4thT/SV	0.060-0.081 (0.070)	0.061-0.077 (0.070)	0.060-0.077 (0.070)	0.061-0.081 (0.070)	0.060-0.081 (0.070)
EN/IN	1.0-1.2 (1.1)	1.0-1.2 (1.1)	1.0-1.2 (1.1)	1.0-1.1 (1.0)	1.0-1.2 (1.1)
EN/SN	0.60-0.72 (0.65)	0.63-0.67 (0.65)	0.60-0.72 (0.65)	0.60-0.69 (0.65)	0.60-0.72 (0.65)
EY/SN	0.80-1.10 (0.95)	0.88-1.06 (0.93)	0.80-1.06 (0.93)	0.88-1.10 (0.98)	0.80-1.10 (0.95)
3rdF/4th T	0.95-1.10 (1.02)	0.97-1.04 (1.00)	0.95-1.07 (1.02)	0.98-1.08 (1.02)	0.95-1.10 (1.02)

Table 2. Call characteristics for *Oreophryne inornata*.

Specimen	Total Calls	Mean Call Length (sec)	Mean Duration Between Calls (sec)	Call Rate (calls/sec)	Dominant Frequency (Hz)
BPBM 16218	33	0.197 (0.110 - 0.261)	3.16 (1.02 - 6.14)	0.30	2150
Uncaptured	29	0.291 (0.261- 0.306)	3.59 (1.63 - 21.76	0.26	2050
BPBM 16251	12	0.278 (0.254 - 0.292)	2.62 (1.81 - 3.45)	0.88	2450
BPBM 16252	25	0.274 (0.225 - 0.300)	7.13 (1.68 - 51.85)	0.16	2450
BPBM 16253	40	0.263 (0.236 - 0.282)	3.75 (1.32 - 36.1)	0.18	2200

Table 3. Data for five egg clutches of *Oreophryne inornata*. Developmental stage is based on comparison to data provided for *Eleutherodactylus coqui* by Townsend and Stuart (1985).

Clutch Number	Sex of Guardian	Number eggs	Egg size (mm) [range (mean)]	Developmental Stage
1	male	22	3.5-5.1 (4.3)	1
2	male	21	3.9-5.6 (4.9)	5
3	?	18	6.2-6.9 (6.6)	8
4	male	10	5.0-6.6 (5.9)	10
5	male	13	7.1-7.9 (7.4)	15

Table 4. Morphological measurements for Oya Tabu sample of *Oreophryne insulana*.

Character	BPBM 16119	BPBM 16546	BPBM 16547	BPBM 16548	BPBM 16549	BPBM 16550	BPBM 16551	Mean
Sex	M	M	M	M	imm F	juv.	juv.	
SV	22.9	21.3	21.9	21.4	16.9	7.9	12.8	20.0
TL(fold)/SV	0.38	0.37	0.37	0.39	0.38	0.46	0.40	0.39
TL(knee)/SV	0.42	0.42	0.41	0.43	0.43	0.48	0.45	0.43
EN/SV	0.096	0.089	0.096	0.093	0.095	0.082	0.086	0.090
IN/SV	0.096	0.094	0.091	0.098	0.095	0.108	0.109	0.095
SN/SV	0.14	0.15	0.14	0.14	0.15	0.15	0.15	0.14
TY/SV	0.044	0.052	0.043	0.051	0.041	0.032	0.035	0.042
EY/SV	0.14	0.15	0.14	0.14	0.16	0.16	0.16	0.15
HW/SV	0.42	0.44	0.43	0.43	0.42	0.42	0.41	0.42
HL/SV	0.36	0.36	0.37	0.37	0.38	0.39	0.35	0.36
HandL/SV	0.28	0.28	0.28	0.27	0.26	0.23	0.28	0.27
FootL/SV	0.43	0.40	0.38	0.40	0.38	0.43	0.38	0.40
3^{rd}F/SV	0.061	0.053	0.054	0.054	0.047	0.039	0.051	0.053
4^{th}T/SV	0.044	0.037	0.040	0.040	0.036	0.035	0.051	0.039
EN/IN	1.00	0.95	1.05	0.95	1.00	0.76	0.79	0.95
EN/SN	0.67	0.58	0.68	0.65	0.64	0.54	0.58	0.63
EY/SN	0.94	1.0	1.0	1.0	1.1	1.1	1.1	1.0
3rd F/4th T	1.40	1.44	1.34	1.35	1.33	1.11	1.00	1.36

Table 5. Morphological measurements for Cloudy Mountains sample of *Copiula minor*.

Character	Specimens													Mean
	BPBM 15665	BPBM 15666	BPBM 15667	BPBM 15668	BPBM 15669	BPBM 15670	BPBM 15671	BPBM 15672	BPBM 15673	PNGNM 23942	PNGNM 23943	PNGNM 23944	PNGNM 23945	
Sex	M	M	M	M	M	M	M	M	F	M	M	M	M	
SV	23.4	24.5	24.0	23.7	23.6	24.9	25.4	24.0	25.3	24.1	23.9	26.2	24.9	24.5
TL(fold)/SV	0.48	0.52	0.49	0.47	0.47	0.49	0.50	0.49	0.48	0.44	0.47	0.43	0.44	0.47
TL(knee)/SV	0.50	0.53	0.52	0.52	0.49	0.51	0.52	0.49	0.53	0.47	0.50	0.47	0.50	0.50
EN/SV	0.073	0.078	0.079	0.072	0.072	0.072	0.075	0.079	0.075	0.071	0.079	0.069	0.076	0.075
IN/SV	0.11	0.11	0.10	0.11	0.10	0.10	0.11	0.10	0.09	0.10	0.11	0.10	0.10	0.10
SN/SV	0.13	0.13	0.14	0.14	0.14	0.13	0.14	0.14	0.13	0.12	0.13	0.13	0.13	0.13
TY/SV	0.056	0.057	0.063	0.055	0.042	0.052	0.043	0.058	0.051	0.054	0.063	0.057	0.056	0.054
EY/SV	0.11	0.11	0.10	0.11	0.10	0.10	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10
HW/SV	0.41	0.38	0.40	0.43	0.41	0.41	0.39	0.41	0.40	0.41	0.42	0.37	0.37	0.40
HL/SV	0.35	0.35	0.34	0.35	0.33	0.33	0.32	0.33	0.34	0.31	0.35	0.32	0.31	0.33
HandL/SV	0.23	0.24	0.23	0.24	0.23	0.23	0.21	0.23	0.23	0.23	0.23	0.23	0.23	0.23
FootL/SV	0.48	0.53	0.49	0.51	0.50	0.49	0.46	0.48	0.51	0.49	0.51	0.46	0.49	0.49
3rdF/SV	0.029	0.031	0.028	0.030	0.034	0.032	0.035	0.028	0.034	0.031	0.034	0.032	0.030	0.031
4thT/SV	0.047	0.049	0.042	0.051	0.051	0.048	0.047	0.046	0.043	0.046	0.050	0.050	0.048	0.048
EN/IN	0.68	0.73	0.83	0.68	0.74	0.69	0.68	0.79	0.79	0.74	0.70	0.67	0.73	0.73
EN/SN	0.55	0.58	0.58	0.53	0.53	0.55	0.54	0.58	0.58	0.57	0.59	0.55	0.58	0.56
EY/SN	0.81	0.82	0.73	0.78	0.75	0.73	0.69	0.76	0.79	0.83	0.75	0.82	0.79	0.77
3rd F/4th T	0.62	0.63	0.68	0.58	0.67	0.66	0.73	0.62	0.78	0.68	0.68	0.64	0.63	0.66

Table 6. Call characteristics for *Copiula minor*.

Specimen	Total Call Duration (sec)	Total Notes	Mean Note Duration (sec)	Mean Internote Duration (sec)	Call Rate (notes/sec)	Dominant Frequency (Hz)
Uncaptured No. 1	4.27	66	0.0378	0.0421	15.32	1180
Uncaptured No. 2	-	43	0.0336	0.0383	13.87	1210
BPBM 15665	2.72	46	0.0258	0.0333	16.96	1400

NOTES ON CAPTIVE REPRODUCTION AND OTHER OBSERVATIONS IN THE RECHERCHE PYGMY DUGITE *PSEUDONAJA AFFINIS TANNERI*

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INTRODUCTION

Maryan and Bush (1996) provided a summary of all available literature on the elapid snake *Pseudonaja affinis* Günther, 1872 including the insular subspecies *exilis* Storr, 1989 and *tanneri* (Worrell, 1961). In their paper, it was stated that no reproductive data were available on either insular race.

Pseudonaja affinis tanneri is known from only Boxer (34°00'S 121°41'E) and Figure of Eight (34°02'S 121°37'E) Islands in the Archipelago of the Recherché. During October 1994 David Knowles visited the latter island and collected *P. a. tanneri* for the Western Australian Museum. It was later decided that some of these individuals be maintained for captive studies, with one pair being maintained by me and one adult male by Brian Bush.

CAPTIVE REPRODUCTION

By January 1997 the female's mass had increased from 11.1 g when collected to 103 g, while the male weighed 240 g. The first attempt to mate these snakes was in September 1999 when the female weighed 357 g. There was significant size disparity, with the male weighing 592 g, although it showed immediate interest in the female. Even though no actual copulation was observed, I assumed that insemination had occurred due to the continual physical pressure applied by male. The female laid a total of 12 unfertilised yellow 'slugs' during 16-17 November 1999. I attributed this failure to a combination of year round heating of the male and possibly the immature state of the female. In hindsight, this insular race probably requires minimal heating as it is exposed to the cool air temperatures of the Southern Ocean.

From March to September 2000 no artificial heat was used in the male's cage. On 20 September I introduced the male to the female with

actual copulation observed at 9:35pm after an initial 4 hr period of vigorous posturing and 'body twitching'. It amuses me how many times a male attempts to copulate with the wrong end. By 25 October it was noticed the female was swollen posteriorly and egg laying was imminent. The female (388 g) was provided with an ice-cream container and dampened vermiculite. On 29 October fifteen eggs were laid and immediately removed for measurement (Table 1). The female's mass after oviposition was 277 g allowing a reproductive effort of 40% to be calculated following Bush (1997). Pre and post-egg laying sloughs in the female occurred at 9 and 29 days respectively. Eggs were placed on a mix of 100 g vermiculite/50 g water (2:1 ratio) and incubated at 30°C.

All eggs hatched between 19-23 December 2000 after 52-56 days incubation (Table 1) and post-natal sloughs occurred between 26 December 2000 and 4 January 2001.

DISCUSSION

Reproductive Output

Clutch size, egg size (mm) and mass (g) are within the recorded ranges of 11-35 eggs, length 25-46, width 15-25 and mass 4.6-13.9 presented by Maryan and Bush (1996) for the nominal race. They presumed that the smaller insular races would have lower fecundities and that Shine's (1989) range of 3-25 eggs for the species probably included at least one of these island populations, explaining the lower clutch sizes he recorded. Considering these data, clutches of 12 and 15 eggs from a pygmy subspecies of *Pseudonaja* are surprisingly high. However, the difference in clutch size presented by Maryan and Bush (1996) compared with Shine (1989) is possibly because large and well-fed captive snakes have the potential for higher fecundity than museum specimens collected from the wild.

Table 1. Egg and hatchling data for *Pseudonaja affinis tanneri*

Egg Length x Width (mm)	Egg Mass (g)	Hatchling SVL (mm)	Hatchling Total Length (mm)	Hatchling Mass (g)
30 x 21	4.9	183	210	4.7
28 x 21	6.0	155	180	3.9
41 x 21	8.1	189	212	5.3
34 x 20	7.3	182	210	4.8
34 x 20	8.3	196	220	5.4
30 x 22	7.9	199	227	4.6
35 x 21	8.3	152	175	3.0
33 x 21	7.5	165	195	4.0
33 x 21	7.5	164	197	3.9
29 x 19	5.4	177	205	3.6
25 x 20	5.0	Infertile		
32 x 21	7.7	183	212	4.5
24 x 20	4.8	157	182	3.0
26 x 20	4.8	201	232	5.6
32 x 21	6.7	Stillborn		

Combat And Sexual Size Dimorphism

The small insular race *P. a. tanneri* displays male-male combat (D. Knowles, pers. comm.) similar to its mainland counterparts. In captivity the adult male often attempted to 'wrestle' my arm by constricting and pushing against it during cage cleaning in the warmer months. The difference in size mentioned previously between the two adult sexes is more noticeable in body mass than in length and still so after nine years of captive maintenance. Shine (1989) found that male *Pseudonaja* spp. tended to only slightly exceed females in mean adult snout-vent length. However he recorded significant correlation between the extent of sexual dimorphism in body size that conclusively showed males were the larger sex in the larger species.

The general view of various authors, including Shine (1994), is that large adult males have evolved as a result of male-male combat. This combat is considered to be part of a competitive 'test of strength' to win conspecific females. Therefore, increased body mass (=muscle) would be more crucial during these interactions than larger adult length. This view is supported by Bonnet *et al.* (1998) who found that males consistently had more musculature (relative to body length) than did conspecific females and

that this body composition facilitated mate-searching activities and male-male combat. This also seems to be the case for *P. a. tanneri*, in which both adults have attained similar body lengths during captivity but differ considerably in body mass. The male is proportionably much heavier and stronger, a feature especially noticeable when being handled. This sexual difference has been noted for other *Pseudonaja* by Bush (1994).

Colour Change

Maryan and Bush (1996) state that dugites maintained in captivity darken with age. Greer (1997) provides an overview of ontogenetic change in colouration in Australian elapids.

The colouration of *P. a. tanneri* hatchlings is similar to that described for the nominal race, having light brown bodies with indistinct dark herringbone pattern and a single large black blotch on the upper part of the head. By eight months old they are black over the dorsum. This overall darkening appears to be caused by an ontogenetic spread of the dark pigment responsible for the herringbone pattern and head blotch. The two adult male *P. a. tanneri* showed a similar darkening after capture. These were brown in colour at capture (Storr *et al.*, 2002: 140) changing to a dark greyish-black after a few months in captivity.

Defensive Behaviour

Brown Snakes are fast moving, nervous and relatively intolerant of interference (Ehmann, 1992). Although shy, when prevented from escape their defensive behaviour (including biting) is vigorous and with the exception of *P. modesta*, all are dangerously venomous. Brown Snakes typically employ a high-intensity defence posture that consists of raising anterior part of the body off the ground in an S-shaped coil, often with mouth open. The low intensity position is similar but with the raised portion of the body held loosely and more elongate with flattening of the neck. Herpetologists familiar with these threat response displays have observed this in both captive-bred hatchlings and wild caught adults.

Juvenile or adult *P. a. tanneri* held in captivity do not show these defensive behaviours. The adult snakes when captured on Figure of Eight Island were also placid with no defensive behaviour shown (D. Knowles, pers. comm.).

Greer (1997) suggested that the varying degree of defensive behaviour in insular populations of Tasmanian Tiger Snakes *Notechis scutatus* may be related to a reduction of predators on many islands. Similarly, *N. scutatus* on Carnac Island are more placid than their mainland counterparts (B. Bush, pers. comm.). The lack of defensive behaviour in *P. a. tanneri* is in agreement with this hypothesis. Boxer and Figure of Eight Islands are relatively remote, undisturbed and uninhabited with ample lizard prey and more recently introduced rodents (Maryan and Bush, 1996).

Unresolved Taxonomy

It has been suggested by Aplin and Smith (2001) that both insular subspecies of dugite are of dubious taxonomic significance in view of the recency of separation of these populations from those on the adjacent mainland. The contentious taxonomy of Tiger Snakes is also mentioned by Aplin and Smith (2001) and probably influenced their suggestion regarding the subspecific treatment of *P. affinis*. The low levels of genetic differentiation in Tiger Snakes across southern Australia prompted Schwaner (1985) to suggest that all populations be placed in a single monotypic species, *N. scutatus*.

However, genetic studies have yet to be undertaken on any of the morphologically distinct forms of *P. affinis*, including the insular race *tanneri*, to determine whether differentiation is at species or subspecies level.

Size has generally been used as the main character to distinguish insular Australian snakes from their mainland counterparts. However, Schwaner (1985) found that insular Tiger Snake sizes were closely correlated with food availability, suggesting that size alone was of little use in subspecific recognition of such populations. Both *P. a. exilis* and *P. a. tanneri* are reported to attain much smaller maximum adult lengths than mainland *P. a. affinis* (maximum snout-vent length up to 1005, 760 and 1670 mm respectively in Storr *et al.*, 2002: 214-5). Lizards are abundant on the islands occupied by both subspecies and it is only in recent times introduced rodents have become available prey items (Maryan and Bush, 1996). However, recognition of *tanneri* as a distinct pygmy subspecies seems validated by the captive adults in this study. Despite being fed a diet of adult mice, they only attained a maximum SVL of 859 mm (Maryan and Bush, 1996). To my knowledge, no *P. a. exilis* have been maintained in captivity.

Another diagnostic feature reported for insular snake subspecies, including the dugite subspecies, is a darker adult coloration. However some individuals of mainland *P. a. affinis* are also entirely black on the dorsum and venter. Furthermore, Aplin and Smith (2001) mention the occurrence of small, superficially *tanneri*-like dugites from the southeastern coastal margin of Western Australia.

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PENETRATION OF THE EGGSHELL AND INVASION OF EMBRYONIC TISSUE BY FUNGI COLONISING SEA TURTLE EGGS

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INTRODUCTION

The fungi *Fusarium oxysporum, Fusarium solani* and *Pseudallescheria boydii* have been isolated from failed eggs of loggerhead (*Caretta caretta*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and flatback (*Natator depressus*) sea turtles in eastern Australia (Phillott *et al.*, 2001, 2004). The invasion of sea turtle nests by these fungi appears to rely on the use of a moribund egg/s as a nutrient focus followed by hyphal spread to adjacent, viable eggs (Phillott & Parmenter, 2001a). Embryo mortality might occur by impediment of respiratory surfaces (Solomon & Baird, 1980; Phillott & Parmenter, 2001b), deprivation of calcium (Solomon & Baird, 1980; Phillott, 2002) or invasion of embryonic tissue (Solomon & Baird, 1980; Phillott, 2002).

To utilise embryonic tissue as a source of nutrients, fungi must penetrate the inorganic and organic layers of the eggshell since the lack of pores prevent direct entry of hyphae and spores from the exterior (Phillott, 2002). Kunert *et al.* (1993) suggested strong proteolytic and lipolytic activity would allow fungi to penetrate reptilian eggshell. A typical strain of *F. solani* invading snake eggs (Kunert *et al.*, 1993) and the plant pathogen *F. oxysporum lycopersici* (Hankin & Anagnostakis, 1975) have demonstrated some of these capabilities (although not all were tested). It is not known if *P. boydii* produces similar hydrolytic enzymes, or if the *F. oxysporum* and *F. solani* isolated from sea turtle eggs produce the same enzymes as those of other strains. Positive activity of the egg mycobiota on specific culture media would indicate the likelihood of *F. oxysporum, F. solani* and *P. boydii* being able to penetrate the turtle egg and utilise the embryonic tissue as a nutrient source. This study tests these three fungi for the presence of enzyme activity, and searches for evidence of fungal invasion of dead embryos.

PROCEDURE

Enzymic activity of the strains of *F. oxysporum, F. solani* and *P. boydii* isolated from failed green turtle eggs at Heron Island were determined according to the procedures of Hankin and Anagnostakis (1975) and Kunert *et al.* (1993). All tests were conducted by central inoculation onto media allowing the detection of amylase, lipase, protease, collagenase and elastinase. In addition, the production of organic acids was detected by growth on Potato Dextrose Agar containing $0.018gL^{-1}$ of the pH indicator Phenol Red (as recommended by Power & McCuen, 1988). Eight replicates of each test per fungus were incubated at room temperature (21-23°C) until colonies were 5-10 mm in diameter.

To detect fungi in embryonic tissue green turtle (*Chelonia mydas*), 19 nests at Heron Island were inspected after hatching and a single large embryo (beyond Stage 26- after Miller, 1985) from a failed egg (with obvious fungal growth) in each nest was surface sterilised by immersion in 70% alcohol for 5 mins. The heart, liver, pectoral muscle, and small intestine were then removed and each organ placed on half-strength Potato Dextrose Agar with $0.05gL^{-1}$ chloramphenicol. Once it was established that fungi could be cultured from all of these tissues, only the liver (being the largest organ) was sampled. Swabs were also taken from the exterior of some of the eggs (as reported in Phillott *et al.*, 2001) to provide a comparison of fungi cultured from the exterior and embryonic tissue of failed eggs.

RESULTS

The lytic effects of the fungi on each medium are summarised in Table 1 as a positive (+) or negative (-) lytic behaviour. All of the replicates for each fungus on each medium showed the same response. *Fusarium oxysporum*, *F. solani* and *P. boydii* all produced the metabolites amylase, collagenase, elastinase, lipase and organic acids, but only *F. oxysporum* and *F. solani* produced protease.

The species of fungi isolated from the cultures of embryonic tissue are reported in Table 2. Fungi were isolated from 65% of the liver samples. Of these cultures, 84.6% were *P. boydii*, 7.7% *F. solani*, and 7.7% a mixed culture of *P. boydii* and *F. solani*. Swabs taken from the exterior of 7 eggs prior to tissue sampling all produced *P. boydii*. In one egg, *P. boydii* was isolated from both the exterior and liver samples, but *F. solani* was also present in this tissue. Three other eggs also had mixed cultures isolated from the embryonic tissues, although fungi was not cultured from the shells of these eggs.

DISCUSSION

Enzymes produced by *F. oxysporum*, *F. solani* and *P. boydii* (see Table 1) would allow invasion of the inorganic component of the sea turtle eggshell and utilisation of the eggshell, albumen and yolk as nutrients. This could ultimately result in embryonic death by processes such as disruption of the eggshell integrity, loss of respiratory surface, invasion of the embryo, and/or embryo malnutrition.

The prevalence of *P. boydii* in tissue samples reflects the occurrence of this fungus on the egg exterior relative to other species. Only one of the seven eggs from which surface fungi was cultured actually had fungi isolated from the liver. Another egg which showed fungi on both eggshell and other embryonic tissues did not have fungi in the liver. These results suggest that single tissue cultures, and possibly the liver tissue itself, may give an underestimate of the real frequency of embryonic invasion by fungi. Alternatively, fungal invasion of embryonic tissue may only occur post-mortem, and the time period between colonisation of the egg and tissue sampling was not sufficient to allow fungal penetration of the eggshell to access the egg contents in all samples. However, post-mortem fungal penetration by more than one species seems unlikely in the presence of only a single external colony.

Previous studies typically show monotypic cultures from the egg exterior, with only 6.5% of samples (n= 107) revealing mixed cultures (1 *F. oxysporum* + *F. solani*; 2 *F. oxysporum* + *P. boydii*, 4 *F. solani* + *P. boydii* – see Phillott et al., 2001). In the event of multiple fungal species penetrating the eggshell yet only a single exterior species, the fungus isolated from the egg exterior may represent the initial invader ("founder") species, or the climax community following competitive exclusion.

In studies of fungal invasion of reptilian eggs it is suggested any external isolates should not be regarded as the causative agent of embryo mortality until there are comparative cultures of multiple-organ tissue samples. Samples should be taken as close to embryo mortality as possible to avoid misdiagnosis that may be engendered by community succession of microbes. If multiple isolates are obtained from the egg exterior and/or tissue, competition studies of the fungi may clarify the order of invasion.

ACKNOWLEDGMENTS

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Table 1. Lytic capability of *F. solani, F. oxysporum* and *P. boydii*.

Metabolite	F. oxysporum	F. solani	P. boydii
		Fungi	
Amylase	+	+	+
Collagenase	+	+	+
Elastinase	+	+	+
Lipase	+	+	+
Organic Acids	+	+	+
Protease	+	+	-

Table 2 Fungi isolated from tissues of dead sea turtle embryos.

(- indicates nil sample taken)

Specimen	Sea Turtle	Liver	Tissue Isolate Heart	Tissue Isolate Muscle	Tissue Isolate Gut	Egg Surface
1	Green	P. boydii	P. boydii	F. solani	P. boydii	-
2	Green	F. solani	-	P. boydii	F. solani	-
3	Green	Nil growth	P. boydii	Nil growth	P. boydii	P. boydii
4	Green	Nil growth	Nil growth	Nil growth	Nil growth	P. boydii
5	Green	P. boydii	Nil growth	F. solani	F. solani	-
6	Green	Nil growth	-	-	-	P. boydii
7	Green	Nil growth	-	-	-	P. boydii
8	Green	P. boydii	-	-	-	-
9	Green	Nil growth	-	-	-	P. boydii
10	Green	Nil growth	-	-	-	-
11	Green	P. boydii	-	-	-	-
12	Green	P. boydii	-	-	-	-
13	Green	P. boydii	-	-	-	-
14	Green	P. boydii	-	-	-	-
15	Green	P. boydii	-	-	-	-
16	Green	P. boydii	-	-	-	-
17	Green	F. solani, P. boydii	-	-	-	P. boydii
18	Green	P. boydii	-	-	-	-
19	Green	P. boydii	-	-	-	-
20	Loggerhead	Nil growth	-	-	-	P. boydii

NESTING BEHAVIOUR IN THE WHITE-THROATED SNAPPING TURTLE *ELSEYA* SP. AFF. *DENTATA* FROM THE JOHNSTONE RIVER, NORTH QUEENSLAND.

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ABSTRACT

Nesting behaviour in wild *Elseya* sp. aff. *dentata* from the Johnstone River, north Queensland, is described based on observations of seven females. Nests were constructed with narrow shafts slanting away from the vertical with enlarged egg chambers in sandy/clay-loam soils. The process of excavation, egg deposition and filling-in typically took around two and half hours, with egg deposition being relative brief compared with other stages. Nesting behaviour in *E.* sp. aff. *dentata* followed the typical sequence observed in other chelids with one exception. When filling-in the nest females would compact the soil by placing both rear feet together on top of the soil covering the nest, with rear limbs fully extended and bearing much of turtle's weight. This 'pressure stand' behaviour does not appear to have been reported in other species of Australian chelids.

INTRODUCTION

While there are a number of accounts of nesting behaviour in Australian chelids (see Legler & Georges, 1993) they only describe seven of the currently recognised 22 species in the family (Wilson & Swan, 2003), occur under a variety of circumstances (e.g, captive, semi-natural and natural) and some are incomplete descriptions or else describe only a single nesting event. Collectively the behaviours described in the accounts tend to follow the conservative and stereotyped sequence of steps of chelonian nesting (see Ehrenfeld, 1979; Hailmen & Elowson, 1992). Some accounts do however point to the existence of species-specific behaviours (e.g., Kuchling, 1993) and the importance of chelonian behaviour generally as a taxonomic adjunct has been noted (Englis, 1962; Ehrenfeld, 1979).

Nesting behaviour has not previously been described for the *Elseya dentata* group (the 'snapping turtles') or any *Elseya* species. The snapping turtle inhabiting the Johnstone River catchment of north Queensland has been recognised as distinct by various authors (Goode, 1967; Georges & Adams, 1996; Cann, 1998; Thomson, 1998 where it is referred to as *Elseya* sp. aff. *lavarackorum*); it remains undescribed and there is presently very little information on the biology of the form despite awareness of its existence by taxonomists for nearly 40 years. The voucher name used for this form is *Elseya* sp. aff. *dentata* (Johnstone) (Georges & Adams, 1996) and it is hereafter referred to as *E.* sp. aff. *dentata*. In this report nest construction and egg-laying in wild *E.* sp. aff. *dentata* is described and compared to published accounts of nesting by other Australian chelids.

SITE DESCRIPTION & METHODS

Observations of nesting occurred over six separate evenings in June 2001, July 2002 and June 2003 along a small spit formed between a large still pool (that forms part of a wet season anabranch) and the main flow of the North Johnstone River approximately 4 km west of Innisfail (17°32'S 146°01'E). The main flow in this section of the river consists of a broad set of rapids. The spit is on a cattle property and the surrounding vegetation consists mostly of a mixture of native and exotic grasses and small stands of Weeping Bottle-brush *Callistemon viminalis* fringing the river. At the time the observations were made, the river was well below wet-season flood levels. This section of the river is under tidal influence with freshwater back-up raising water levels by up to 0.5 m. Nesting behaviour in *E.* sp. aff. *dentata* was observed only at night

and there was no evidence to suggest that it also occurred during the day.

A 55 W quartz-halogen spotlight connected to a 12 V battery was used to locate turtles initially and then the switch was made to a 2 W headlamp so as not to unduly disturb females attempting to nest. Nesting was observed from behind the females (at a distance of about 0.5 m) where a clear view of the process was had. Flash photography was used to capture some stages of nesting and this did not cause any apparent disruption or alteration of behaviour. Air temperature, the duration and sequence of events in the nesting process, and general behaviour were recorded. As it was sometimes the case that several females were nesting and being monitored simultaneously, some error in the duration of nesting events was introduced and is stated. The carapace length of females was measured to the nearest 5 mm using a flexible tape measure, as were nest dimensions and clutch size.

OBSERVATIONS

The description of nest construction and egg-laying below is based on the observations of seven females observed nesting in the wild. A single general description of nesting is given since the observations of nesting females were all very similar. In addition to these,

nests that had been started but not completed (i.e., shallow hole no eggs; n = 7) or aborted nesting attempts (i.e., females that emerged from water but did not dig; n = 10) that were witnessed also form part of the general observations described below.

Females emerged from the river between the hours of 8 pm through to 3 am. They walked a distance of between 4 and 12 m (n = 9) from the water's edge to the nest site and then began to dig. Females that were searching for nest sites, or had just commenced clearing the ground, were easily disturbed and would usually retreat to the water if subjected to even slight disturbances. However, once digging had commenced females were quite approachable, though disturbance was kept to a minimum.

The details of the females in which nesting was observed in its entirety (or close to it) are given in Table 1. The total nesting time quoted in Table 1 refers to the time period measured from the commencement of surface scraping/digging to the time females left the nest (stages iii, iv and v below). All females observed nesting during the 2001-2003 seasons did so on wet evenings with intermittent or persistent showers or evenings following wet days, with >5/8 cloud cover and temperatures in the range 17-19°C (Turner, in prep.).

Table 1: Data on seven female *Elseya* sp. aff. *dentata* observed nesting on the banks of the North Johnstone River, Innisfail, during 2001-2003 seasons. Time errors exceeding five minutes are stated and averages are given in the last row.

Female #	Date	Carapace Length	Excavation Time	Egg Laying Time	Total Nesting Time	Clutch Size
1	19.vi.01	250 mm	75 min	28 min	2 hrs 45 min	8
2	25-26.vi.01	300 mm	64 min	25 min	2 hrs 39 min	11
3	26.vi.01	275 mm	67 min	14 min	2 hrs 11 min	10
4	18.vii.02	345 mm	45±10 min	20 min	2 hrs 50 min	10
5	19.vii.02	320 mm	>35 min	32±10 min	>2 hr	7
6	19.vii.02	295 mm	75±20 min	<35 min	2 hrs 15 min ± 15 min	8
7	23.vi.03	280 mm	70 min	10 min	2 hrs 10 min	9
Mean		295 mm	69 min*	19 min†	2 hrs 31 min†	9

*excluding #4, 5 and 6; †excluding #5 and 6.

Nesting

There were six stages in the nesting process (i) emergence from the water, (ii) selection of a nest site, (iii) excavation of the nest, (iv) egg deposition (and manipulation), (v) filling-in of the nest and (vi) returning to the water. Photographs of stages (iii), (iv) and (v) are presented in Figures 1 to 5. In Table 1 times are given for some of these stages. Excavation was the most time-consuming stage, followed by filling-in the nest; the egg-laying time (including egg deposition and manipulation) was relatively brief. The time taken to locate a suitable nest site seemed quite variable but was usually less than 30 minutes and the time taken to return to the water from the nest site was in all observed instances less than five minutes.

Females were observed to approach the spit from both up- and down-stream locations and were seen to make their way along the edges of the rapids in the early evening. They were typically observed in shallow water with their feet on the substrate with the anterior head protruding from the water. Females disturbed at this time would usually submerge and retreat into deeper water. Females would usually sit in the shallows in the posture described for as little as 15 minutes through to several hours before emerging from water. Many females were quite persistent, being sighted repeatedly throughout an evening in different positions in the shallows, having been disturbed by the spotlight. Female 2 was initially seen almost completely out of the water but retreated, only to emerge 15 mins later, several metres down stream. Female 3 was initially seen and captured in the shallows on 11.vi.01 and was seen out of the water scratching at the ground at approx. 8 pm the night before it nested (25.vi.01). Another female was observed to walk up the set of rapids, staying close to the water's edge with the carapace almost completely out of the water but head always underwater. It reached the top of the rapids and continued up and around into the anabranch from which it later emerged to nest.

Females emerged from the water and tended to walk in a direct line up the bank. When obstacles, such as grass tussocks or logs were encountered the females would walk around them and tended not to resume their initial course. They would occasionally pause, resting the plastron against the ground. It is unclear what criteria females used to select a nest site. Females typically abandoned nest sites on very stony ground as was evidenced by the presence of partially excavated nests at these sites, instead preferring to excavate nests in alluvial sandy or clay loam soil that covers most of the spit (see Table 2). The nests of all seven females were located within 12m of the water's edge. Females nested on both inclined and flat ground and often near the base of grass tussocks where they were quite well concealed during the nesting process, although some nested in completely open situations (low, grazed, grass of height < 0.1 m).

Having selected a site, females commenced digging. They began by scraping the ground surface with their rear limbs, alternating left-right, removing surface grass and below this matted grass roots and small stones. In some instances small stones were projected a considerable distance by the force. The front limbs were not used in this process, instead they remained still and appeared to stabilise the shell against the forces applied by the rear limbs. Females were typically orientated with their heads pointing away from water (in the direction they were walking), although those nesting on slopes would reorientate themselves so that their head pointed up the slope.

Once debris was cleared, the rear limb movement changed from a scraping to a digging action in which the force applied by the rear limb was directed downwards rather than sideways. At this stage the rear limbs were used in a more repetitive fashion, alternating after every digging action without exception. The rear limbs would reach down into the hole and scoop-out soil by 'cupping' the foot and then lift it to the surface (Figure 1). The

soil was then deposited on the surface towards the rear of the nest. Often several scrapes with the rear limb were made before sufficient soil was gathered and the foot lifted to the surface. The foot would then usually be placed on the freshly excavated soil, which tended to compact it, as the other limb was lowered into the hole. This action, along with the fact that the soil was moist, prevented it from falling back into the hole. Over time the excavated soil tended to form two patches to the left and right of the rear carapace. With each change-over, the entire carapace was re-positioned so that the rear limb was within reach of the chamber and then lowered down. Viewing the process from directly above, the shell was seen to pivot about the anterior tip of the carapace. The rear limbs reached down in excavating the hole or shaft. There was typically a pause between placing the limb down into the hole and commencing to dig but the digging, lifting and deposition of soil was generally done in a single contin-uous action. The other rear limb at this time was used to support some of the weight of the shell and was placed on the surface beside the hole. While the excavation of the shaft was performed by a vertically downwards digging action, this later changed to a down-ward and forward digging action to excavate the egg chamber. In the latter stages, the front limbs were extended slightly so that the pos-terior marginal edge of the carapace was lowered partly into the hole and the rear limbs were fully extended. This presumably facilitated greater reach, downwards as well as forwards into the egg chamber. Rear limbs alternated some 30-40 times before nest excavation was completed.

Completed nests were typically constructed with the shaft slanted away from the vertical and with a smaller diameter than the egg chamber (Figure 6). It follows that the nest entrance was not directly above the eggs but to one side. Some nest dimensions are given in Table 2.

There was a relatively brief pause (< 5 min) between the cessation of digging and the commencement of egg-laying. During egg-laying there was always one rear limb down the chamber. The rear limbs were used to manoeuvre eggs forward into the chamber and this typically occurred after each egg was laid. Thy were alternated but not in a regular, predictable way as was the case in nest exca-vation. The rear limb was also possibly used to cushion the fall of some eggs (Figure 2). On several occasions an egg was 'caught' during its fall between the limb and the shaft wall. The limb was then used to lower the egg down into the chamber. Eggs were generally deposited one at a time and in relatively quick succession, though occasionally two eggs were released in the one movement. Times between successive eggs being deposited

Table 2. Nest dimensions of eight *Elseya* sp. aff. *dentata* nests on the banks of the North Johnstone River, Innisfail, during 2001-2003 seasons. Averages are given in the last row.

Female	Nest Entrance Dimensions	Slanted Nest Depth*	Substrate Type
1	90 x 90 mm	160 mm	Clay loam
-	100 x 85 mm	190 mm	Sandy loam
-	80 x 75 mm	NA	Sandy loam
4	110 x 80 mm	130 mm	Clay loam
5	100 x 85 mm	150 mm	Sand loam
6	85 x 80 mm	130 mm	Sandy loam
-	110 x 90 mm	150 mm	Sandy loam
8	100 x 65 mm	140 mm	Sandy loam
Mean	99 x 81 mm	150 mm	

* Measured from the nest surface opening to the bottom of the egg chamber.

ranged from 15 seconds through to 4 minutes. Some eggs made an audible 'clunk' as they hit the substrate or other eggs in the nest. At the end of egg deposition the rear limb was used to again push eggs further forward into the chamber prior to filling-in.

The filling-in stage occurred within minutes of egg deposition being completed. This involved the rear limbs alternately reaching back to the soil deposited at the rear of the nest followed by a sweeping action that moved soil into the chamber. The sweeping extended radially outwards as the filling-in progressed. Small stones and grass were dragged in over the nest.

At different times during the filling-in process the rear feet were placed together in the partially filled-in chamber, sometimes one foot on top of the other, with the rear limbs extended fully so that the entire weight (or close to it) of the turtle bore-down upon the soil above the nest (Figure 3). Females would tremble and appeared unsteady as they did this since the stance involved considerable balance to maintain. Females were observed to use this 'pressure stand' between two and four times during the filling-in stage.

On completion of the filling-in stage, females would immediately begin walking back to the river. Females walked in more or less a straight line (no observation available for Female 1). Their path back to the water did not usually correspond to their path out of the water, but tended to be more direct. Females 2 and 3 re-entered the water where the bank was vertical and dropped from a height of nearly 1 m into the water. They initially appeared to experience a buoyancy problem, bobbing on the surface, but after expelling four or five large air bubbles they sank to the river bottom and commenced walking along it.

Completed nests were well disguised and apart from patches of muddied grass there were no obvious visual signs of their presence (Figure 4). Nest entrances could not visually be distinguished from surrounding ground.

The soil used to plug the nest entrance was quite solid (due to it being compacted). On locating the egg chamber it was noticed that quite large air gaps existed in between the eggs and also between the eggs and the roof of the chamber (Figures 5 & 6). Eggs were hard-shelled, clean, moist and translucent.

DISCUSSION

Nesting behaviour has been described in relatively few species of Australian chelids: the Eastern Long-necked turtle *Chelodina longicollis* (McCooey, 1887; Waite, 1925; Harrington, 1933; Vestjens, 1969; Wells, 1973; Hill, 1979; Kennerson, 1979; Georges, 1984; Beck, 1991; Green, 1997), Western Long-necked turtle *Chelodina oblonga* (Russ, 1970; Nicholson, 1975; Clay, 1981), Murray River turtle *Chelodina expansa* (Goode, 1965), New Guinea Long-necked turtle *Chelodina novaeguineae* (Curtiss, 1928), Macquarie River turtle *Emydura macquarii* (Barrett, 1929; Goode, 1965; Green, 1996), Jardine River turtle *Emydura subglobosa* (Nicol, 1992) and the Western Swamp turtle *Pseudemydura umbrina* (Spence *et al.*, 1979; Kuchling, 1993). The accounts vary considerably in the amount and type of details provided, therefore making comparisons within and between species difficult. However nesting behaviour in *E.* sp. aff. *dentata* is generally similar to that described for other chelids (except *P. umbrina* which is excluded from comparisons) with some notable differences and these are discussed below.

The duration of nesting events in *E.* sp. aff. *dentata* was fairly consistent, however, comparison with other Australian chelids is difficult due to the limited published data on this aspect. One factor that that is likely to affect nesting duration is the nature of the soil substrate in which turtles nest (Harrington, 1933; Vestjens, 1969) and excavation times do reflect this. They vary greatly from around half an hour in sand (Harrington, 1933; n = 1) through to approximately five hours in ground that was 'dry and hard' due to drought (Green, 1997; n = 1). Egg-laying

Figure 1. Excavation of the nest. In this figure the cupped foot is lifting clay-loam soil to the surface where it is then deposited at the edge of the opening in the foreground.

Figure 2. Manipulation of the eggs into the chamber. In this figure the eggs are being moved forward into the nest chamber by the rear limb.
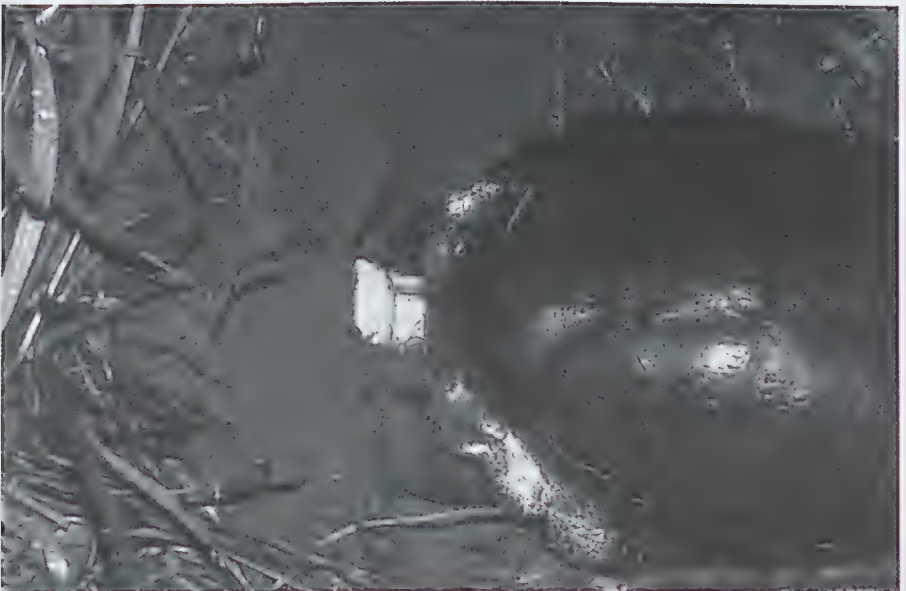
Figure 3. Filling-in the nest. In this figure the 'pressure stand' is shown in which the both rear limbs are placed on top of the partially filled-in nest, with feet together and rear limbs not yet fully extended.

Figure 4. The surface of a nest soon after completion.
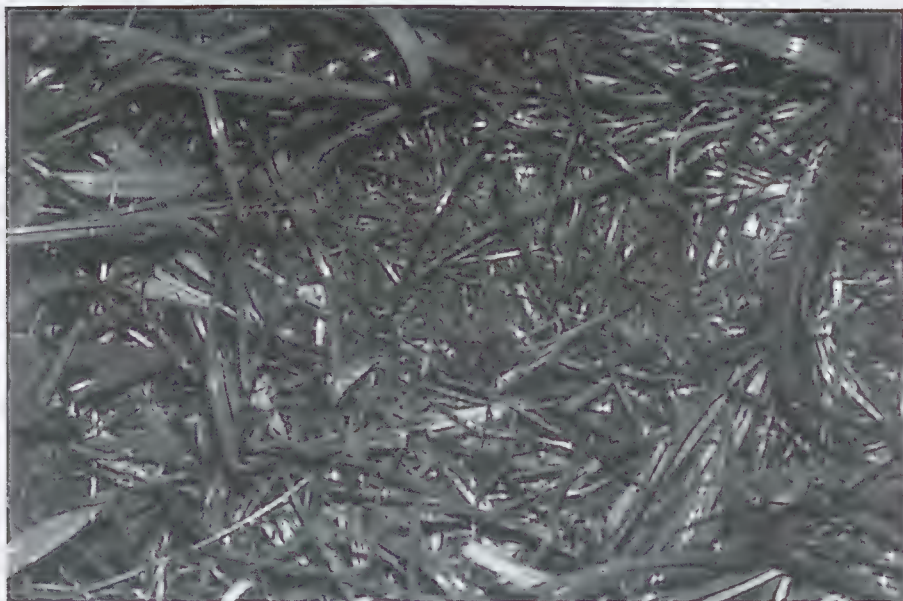
Figure 5. A partially excavated nest chamber. In this figure the positions of five undisturbed eggs within the nest chamber are shown. Visible also are air pockets separating eggs. There were ten eggs in the clutch.
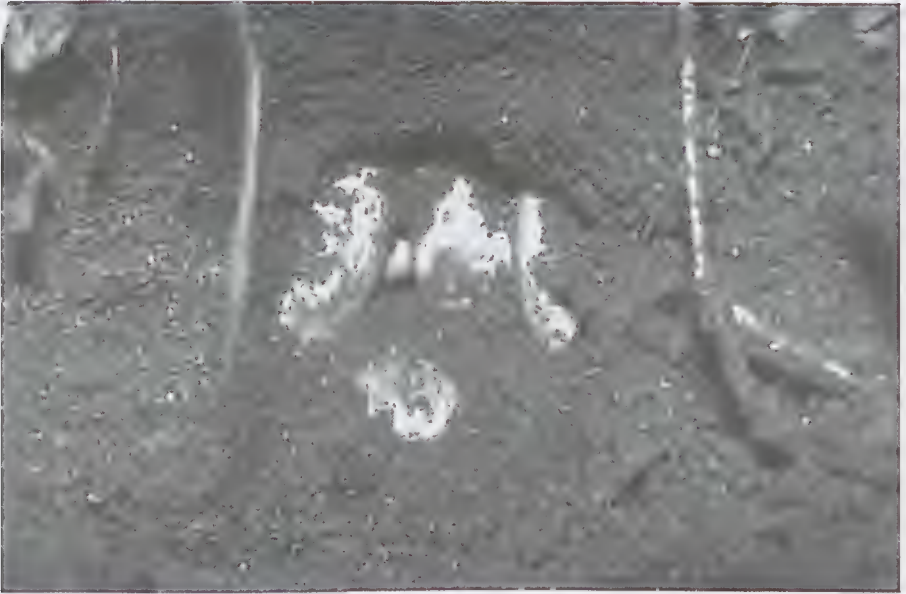
Figure 6. Profile of a typical *Elseya* sp. aff. *dentata* nest.
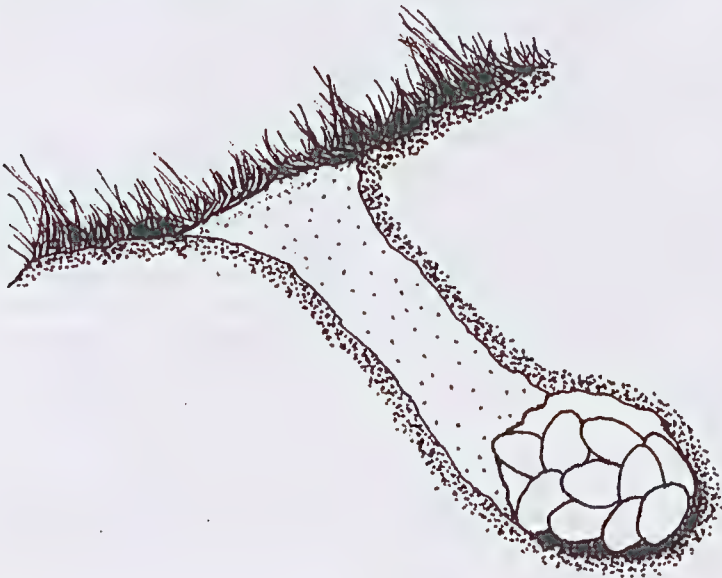
was relatively brief in *E*. sp. aff. *dentata* compared with other stages of nesting and this was generally the case for other chelids (Goode, 1965; Vestjens, 1969; Clay, 1981; Green, 1997) but exceptions do exist (Hill, 1979; Beck, 1991).

The behaviour of females emerging from the water has been mentioned in only a few accounts. Green (1996) noted that female *Emydura macquarii* waited until the sun had set before emerging from the water to nest. He further noted that females were 'shy' and that it was difficult to approach them until egg-laying had begun. Clay (1981) observed female *C. oblonga* sitting in shallows with their heads well above the water line prior to emerging and then doing so very cautiously, being easily disturbed and retreating into deeper water when disturbed. These observations parallel those observed in *E*. sp. aff. *dentata*. Clay (1981) also noted that once females were 'some distance' from the water's edge they were not easily disturbed in contrast to *E*. sp. aff. *dentata* females that were sensitive to disturbance until digging was underway.

Cloacal discharge has been observed or inferred in some chelids as a precursor to digging (e.g., McCooey, 1887; Curtiss, 1928; Goode & Russel, 1968; Wells, 1973; Hill, 1979; Kennerson, 1979; Beck, 1991) and/or sometimes during digging (Hill, 1979; Green, 1997) and mostly in situations where the ground was dry. Vestjens (1969) did not notice any cloacal discharge in the 21 observed nestings of *C. longicollis* that took place during wet conditions, yet in dry conditions cloacal discharge has been observed in this species (e.g. Green, 1997). It was not observed in *E*. sp. aff. *dentata*, perhaps not surprisingly given the wet conditions and moist substrate that existed at the time of each nesting.

The alternate use of the hind limbs in excavation as observed in *E*. sp. aff. *dentata* has been mentioned in nearly all accounts and almost without exception occurred after every scoop of soil was brought to the surface (but

see Beck, 1991). Manipulation of eggs into the egg chamber has also been observed in most species but the use of the rear limb to cushion the fall of eggs has been observed to a lesser extent (Goode, 1965; Vestjens, 1969; Russ, 1970; Nicholson, 1975; Cann, 1978; Hill, 1979; Clay, 1981; Beck, 1991; Green, 1996, 1997).

One behaviour that has not been noted in other chelids is the 'pressure stand' that *E*. sp. aff. *dentata* uses during the nest-filling stage. Its purpose appears to be to compact soil above the egg chamber and hence create a seal or soil 'plug'. Given that incubation occurs during some of the driest months of the year (August-November) this may slow or prevent the dehydration of eggs. Stamping the substrate with the plastron (during the latter stages of filling-in the nest) has been observed in other species and would appear to serve a similar purpose (*E. macquarii* Goode, 1965; *C. longicollis* Vestjens, 1969; Cann, 1978; Hill, 1979; Kennerson, 1979; Green, 1997; *C. oblonga* Russ, 1970; Nicholson, 1975; Clay, 1981; Beck, 1991).

A close inspection of the freshly laid hardshelled eggs of *E*. sp. aff. *dentata* revealed that some had extensively fractured regions of the calcareous shell layer, though the eggs retained their shape, integrity and viability. Shell cracking seems to have resulted from their impact with the substrate and/or other eggs. Vestjens (1969) recorded eggs of *C. longicollis* that were punctured by the claws from the hind limb, while presumably being positioned in the nest chamber and Wells (1973) observed that one egg (of 12) in a *C. longicollis* nest was cracked during laying. The hard egg shell and blunt-ended claws of *E*. sp. aff. *dentata* make this type egg mortality unlikely and none was observed.

Many accounts state that completed nests were inconspicuous compared to their immediate surroundings (e.g., Harrington, 1933; Goode, 1965; Clay, 1981; Nicholson, 1975; Green, 1997; but see Nicol, 1992). While this was also the case for *E*. sp. aff. *dentata*,

predators were able to locate and destroy almost all nests soon after deposition (Turner, in prep.)

It is evident that detailed observations on nesting behaviour of other *Elseya* species would be useful in identifying features of nesting behaviour that may be unique to *E. sp. aff. dentata* or for the genus.

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HERPETOLOGICAL NOTES

OBSERVATIONS OF A HYLID FROG *LITORIA DAHLII* (BOULENGER, 1896) FEEDING ON A ROAD-KILLED DEATH ADDER

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The hylid frog *Litoria dahlii* is a slender yet large frog with an average length of 70 mm (Cogger, 1992). It is found from the west of Cape York, Queensland, across the Top End of the Northern Territory, where it inhabits savanna woodlands, particularly floodplains. It is commonly encountered active at night around billabongs, swamps and lagoons and can also be seen on nearby roads, especially during and after rain (pers. obs.).

On 8 April 2002, I was driving south along the Arnhem Highway, Northern Territory, which is a well-known area for observing numbers of reptiles and frogs (Hoser, 1989). There was a light rain that had been consistent for approximately an hour, no wind, air temperature was 24°C and there was a quarter moon. At 2136hrs, approximately 1.5 km from the Adelaide River and 24 km S of Humpty Doo (12°39'45"S 130°20'15"E), with the high beam of my car lights, I spotted a road-killed snake in the middle of the bitumen road. On closer inspection with a hand torch, the snake was identified as an adult male Top End Death Adder (*Acanthophis* cf. *praelongus*) approximately 350 mm snout-vent length, and I observed that it was being fed on by an adult *Litoria dahlii* approximately 65 mm in length.

The snake was half-curled upside down, and appeared to have been recently killed. There was fresh blood from the mouth and a ventral wound exposing internal organs. I watched the frog feed on the stomach and intestines of the snake, taking big mouthfuls at a time. This feeding continued for approximately three minutes, until all of the visibly exposed organs were eaten.

At this point, the frog ripped the skin of the wound further apart by placing its left hand on the body of the snake and using its mouth to tear the skin and expose more of the snake's organs, and continued to feed. After one minute of further observations, I had to return to my car as traffic was approaching. On returning to the road-kill shortly afterwards, the frog was gone.

To my knowledge, this feeding behaviour has not been documented for this species. Deliberate on-road feeding by another Australian frog, *Helioporus australiacus*, was described by Hoser (2002).

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AN UNUSUALLY LARGE BASKING AGGREGATION OF *CRYPTOBLEPHARUS VIRGATUS* (GARMAN, 1901) (LACERTILIA: SCINCIDAE) IN SYDNEY

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Cryptoblepharus virgatus (Garman, 1901) is a common small skink in south-eastern Australia. In urban areas it is commonly found on brick walls of houses (Hoser, 1989).

This note describes an unusually high number of skinks basking at a single site. Nineteen mainly adult *C. virgatus* and a single adult *Lampropholis guichenoti* were observed together on 7 May 2002 at about 2.30pm at 84 Hermitage Rd, West Ryde. The weather was clear and sunny and the air temperature was about 22°C. The location was at the front wall of a factory in a street full of small factories, car repair shops and the like.

The aggregation was observed on a flattened sandstone rock in front of the factory wall and about 5 m from the roadway. The rock was more-or-less rectangular in shape, about 60 cm long, 30 cm wide and 20 cm thick. It was sitting on hardened muddy soil and surrounded by an area of basically bare dirt.

The isolated nature of the rock made it possible to catch and accurately count the lizards. Lizards were caught as they moved about the rock surface, or by lifting the rock and grabbing lizards as they fled or rested on the underside.

At the time the aggregation was first seen, all or most of the lizards were actively basking and moving about the rock surface. They were observed for a short time before being caught, and no agonistic behaviour was observed between the lizards, although it was noted that the lizards did not bask on one another and tended to move about without making physical contact with one another.

The explanation for the large number of skinks being congregated on a single rock appears to relate to the location of the rock and the time of year. The rock was apparently the only suitable basking spot in the immediate vicinity. Other walls were generally shaded or lacked crevices and other close retreats for the lizards. There were no other suitable rocks or areas of debris to provide refugia for the lizards in the vicinity.

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LIZARD PREDATION OF FROG SPAWN

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On 14 Feb 2004 I was sitting by the edge of an urban frog pond in Narraweena, NSW, when I observed a large Water Skink (*Eulamprus quoyii*) make its way across about two meters of open lawn to the edge of the pond. It hung over the edge of the near vertical rock wall of the pond edge and appeared to be looking for something. There was a fresh spawn of the Striped Marsh Frog (*Limnodynastes peronii*) by the side of the pond and the lizard immediately moved to a point above it and, descending the side, placed both front feet on the spawn. It then picked off every visible egg from the surface - occasionally wiping the side of its head against the spawn or the surrounding rocks to remove slime.

Initially I thought it was removing small insects from the spawn but as all the eggs disappeared it was clear what was happening. What followed was even more interesting.

When all the visible eggs were consumed on the spawn's upper surface, the lizard rolled the egg mass by keeping its back feet anchored in place but alternately pulling back one front foot after the other to expose new eggs on the side of the spawn previously below water. These were consumed as before. After a while the lizard left and I was able to examine the spawn and verify that there were few eggs visible on the outside although there were no doubt many eggs still safe within the foam. This behaviour was not observed again but over the next couple of weeks *L. peronii* spawns were examined and those in contact with the pond edge were noted to have few or no visible eggs, either on the upper surface of the spawn or on either surface.

I don't know if this behaviour is common in *E. quoyii*, or whether it was confined to this individual.

BOOK REVIEW

A COMPLETE GUIDE TO REPTILES OF AUSTRALIA

Australia's striking reptile fauna has long had just one comprehensive reference work for those interested in identifying these animals. Hal Cogger's Reptiles and Amphibians of Australia, now in its 6th edition (Cogger, 2000), has been widely regarded as the 'bible' for Australian herpetology. However, other works have been available that aimed to cover the fauna, notably by Steve Wilson and collaborator David Knowles, who produced "Australia's Reptiles" in 1988 (Wilson & Knowles, 1988) and later transferred this coverage of Australia's lizards and snakes (no crocs or turtles) to a CD format. These works emphasised encyclopaedic coverage by colour photographs (Cogger's works have never illustrated all species), but omitted technical details and keys in favour of more natural history information.

This new book, now teaming Steve Wilson with noted NSW herpetologist Gerry Swan, continues the approach of the earlier works, but refines and concentrates the information to emphasise identification. This places it in the ambit of Cogger's book, but it differs in relying on identification features that are superficially visible and avoiding the use of keys or identification characters that are internal or microscopic. As Cogger's sixth edition is also rumoured to be his last, 'A Complete Guide' seems destined to become not only the most recent guide to Australian reptiles but also the only one currently available aiming to enable identification of every species. Given this level of influence and potential use, how well does it do? To cut to the chase, I think it does well. With a few amendments in the inevitable next edition it should do even better.

The book's layout is conventional. There is a brief introduction followed by a glossary and two pages of well-executed line diagrams that show the major anatomical features in the major groups of reptiles. A small section of habitat shots from around Australia follows, and then the descriptive accounts. The book ends with selected reading and an index to species, genera and common names used. On the last subject, use of newly coined common names is largely avoided in this book, only better-established common names being used. For each family there is an approximately one-page introduction, then the genera are presented in alphabetical order, within which the species are also described in alphabetical order. Generic descriptions are used to provide important features common to all species or to highlight areas of variability between species. These generic descriptions also provide a thumbnail sketch of the general habits and habitat of the included species, emphasising features that would aid identification under field conditions.

The taxonomy of Australian reptiles is still being established based on new discoveries and analyses, so the taxonomy used in the book differs in places from that used by Cogger and other publications. Partly this reflects new work since 2000, but there are some groups where there are disagreements or inconsistencies in published taxonomic studies, and so the authors of a book such as this are forced to make choices. The taxonomy used in 'A Complete Guide' is a reasonable compromise. Elapid snakes are perhaps the family whose taxonomy differs most to that of Cogger because Wilson and Swan have adopted the generic rearrangements in Allen Greer's snake book (Greer, 1997), many of which are likely to be further supported by evolutionary studies in progress by John Scanlon.

Typically there are five to six images on most pages, the layout varying and image size varying, from 60 x 28 mm to 122 x 80 mm (half-page). Colour, pattern and shape are insufficient to identify many species, so the book does include a significant number of line diagrams that show particular details, such as scalation features, that might be necessary to identify members of some groups. A distribution map is provided for each species, the standard map of Australia with a coloured patch to show area occupied.

The aim of 'A Complete Guide' is to aid the identification of all species of Australian reptiles. This ambitious aim is tempered by advice in a subsequent paragraph that it should be used in conjunction with other books. Slightly self-defeating, perhaps, but realistic. The book is evidently aimed at being something close to an ornithology-style field guide; portable, concise, focused on identification. Unlike the vast majority of birds, a significant number of reptile species show great individual variation in colour and in details of pattern. To show this variation in a comprehensive guide (836 species are included) would seriously compromise the book's asset of portability. Australia just has too many reptiles to adequately cover them all in a single, easily portable volume. So 'A Complete Guide' has to settle in most cases for a single image of each species. This is a limitation, but in spite of that the authors have done well. The great majority of photographs in the book are clear and well chosen; very well chosen given the headache of having to make one image do for often very variable subjects.

I rate this book a success in making its necessary compromises, but I could imagine several changes that would make the second edition of this book a real advance on this first edition. Most of these would target which images are shown at larger or smaller sizes, in order to keep the book's compact size but at the same time make best use of the space. I think the aim should be to maximise the likelihood of making a correct identification, and, in a minority of cases to convince an observer that some species are so similar that a reliable identification may not be possible without expert knowledge. It is not so much the choice of images I fault as the choices that have been made in the layout and sizing of images. While the designers have done a remarkable job in shoehorning all these animals into the small space of this book, it seems to me that not enough thought was given to which species should receive the larger images and which the smaller. And I think the smallest image size, 60 x 28 mm, is just too small except in the case of very distinctive animals.

In some cases the images fail because they do not enable the reader to see the details necessary for identification. One case would be the leaf-tailed geckos, *Saltuarius*, famous for their camouflage. The images are all small, and most show such well-camouflaged individuals that the detailed shape and ornamentation of the animals, as well as colour pattern details (a "V-shaped mark" versus a "wide, open V-shaped mark") are too blurry to appreciate. In the majority of photographs of *Lerista* species it is not possible to see how many legs are present, much less how many toes, so the photographs are of little use in making an initial identification. In other cases, the pose of the individual fails to show vital details that would permit recognition. For instance, the shot of *Varanus p. panoptes* has the tail tip concealed, yet this is the one part of the description emphasised by boldface type. Examples of other photographs that I thought were poor or inadequate for identification include those of *Egernia frerei*, *E. whitii*, *Ctenophorus isolepis*, *Pogona vitticeps*, *Rankinia diemensis* and *Pseudonaja textilis* (adult).

A game always played when a photographic compilation like this appears is 'spot the mistake'. It is no reflection on the expertise of the authors to say that mistakes are a virtual certainty when dozens of photographers provide images of subjects photographed, in some cases, many years ago. When those photos are of species with several very similar relatives, quirks of light or personal experience with particular colour patterns are sometimes enough to either confuse or make plain the identity of an animal in a photograph. That said I found very few errors in identification; the book has been thoroughly debugged.

One error may be an editorial transposition: the *Diplodactylus "damaeus"* from Windorah is a *D. stenodactylus* while the *D. "stenodactylus"* from Sturt NP on p.63 is a *D. damaeus*. On p. 189, both specimens of *C. strauchii* have the appearance of *C. s. strauchii*; the dorsal pattern of *C. s. varius* is almost, or actually, unmarked. The *Varanus "baritji"* on p. 339 is a *V. storri*.

My strongest suggestion for the next 'Complete Guide' would be to abandon the alphabetic arrangement of species. It would help enormously if similar species could be depicted side by side, and images chosen that as far as possible show comparable poses so that subtle differences can be seen. Importantly it would help to emphasise how difficult it is to distinguish some species, and will encourage users of the book to be aware of where simple external appearance may be inadequate for identification. The alphabetic index at the back caters for those wishing to find a particular species.

A second suggestion would be to increase the number of diagrams of useful scalation features. There are many opportunities where such relatively easily observed physical features could be added to help with species that have ambiguous colour patterns. Many of these are already mentioned in the text, but users unfamiliar with a species or group will more readily comprehend these features if provided with a diagram.

A third suggestion for convenience would be to move the distribution maps to the outer margin of the page where they would be far easier to see. The present layout inconveniently places the maps hard against the book's spine. In herpetology, where an animal is found is almost as important as what it looks like, geographic info should be displayed as prominently as possible.

I received my copy just in time to put it to practical use, on my first visit to the Top End for the Australian Society of Herpetologists meetings outside Darwin. I am not familiar with many of the species in the area so genuinely needed a guide I could rely on. In most cases I found 'A Complete Guide' did the trick. Most of the photographs are well chosen and the information with them is good enough to enable unambiguous identification. In a few cases the Guide got me close but it was clear that a difficult group was involved (*Diporiphora, Gehyra*). Moreover the book's size makes it so convenient. It positively encourages you to have it with you on a walk or a drive, and a book in the hand is a hell of a lot more useful than any number of references back in the office or study. Anyone with an interest in Australian reptiles should have this book with them on any field trip. To pinch an advertising phrase: don't leave home without one.

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NOTES TO CONTRIBUTORS

Herpetofauna publishes articles on any aspect of reptiles and amphibians. Articles are invited from interested authors particularly non-professional herpetologists and keepers. Priority is given to articles reporting field work, observations in the field and captive husbandry and breeding.

All material must be original and must not have been published elsewhere.

PUBLICATION POLICY

Authors are responsible for the accuracy of the information presented in any submitted article. Current taxonomic combinations should be used unless the article is itself of a taxonomic nature proposing new combinations or describing new species.

Original illustrations will be returned to the author, if requested, after publication.

SUBMISSION OF MANUSCRIPT

Two copies of the article (including any illustrations) should be submitted. Typewrite or handwrite (neatly) your manuscript in double spacing with a 25mm free margin all round on A4 size paper. Number the pages. Number the illustrations as Figure 1 etc., Table 1 etc., or Map 1 etc., and include a caption with each one. Either underline or italicise scientific names. Use each scientific name in full the first time, (eg *Delma australis*), subsequently it can be shortened (*D. australis*). Include a common name for each species.

The metric system should be used for measurements.

Place the authors name and address under the title.

Latitude and longitude of any localities mentioned should be indicated.

Use the Concise Oxford Dictionary for spelling checks.

Photographs – black and white prints or colour slides are acceptable.

Use a recent issue of Herpetofauna as a style guide.

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Marbled gecko, *Christinus marmoratus* (top) and giant burrowing frog, *Limnodynastes interioris* (below) from Ulandra Nature Reserve. See article on p. 2.
(Photos: G. Daly.)